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FOR

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CONSTITUTION*

ARTICLE I

The name of this Association shall be the American Society for Horticultural Science.

ARTICLE II

The object of the Society shall be to promote the Science of Horticulture.

ARTICLE III

Voting members: Any person who has a baccalaureate degree and holds an official position in any agricultural college, experiment station, or federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

Associate members: Any person not eligible to voting membership will be eligible to associate membership upon vote of the executive committee. Associate members shall not vote and will present papers only at the request of the program committee.

ARTCILE IV

Meetings shall be held annually at such time and place as may be designated by the Executive Committee, unless otherwise ordered by the Society.

ARTICLE V

The officers shall consist of a President, a Vice-President, a Secretary-Treasurer, and sectional chairmen to represent the subject-matter sections of the Society.

ARTICLE VI

The Constitution may be amended by a two-thirds vote of the Society at any regular meeting, notice of such amendment having been read at the last regular meeting.

BY-LAWS*

Section 1—*Duties of Officers:* The President shall preside at business meetings and general sessions of the society, deliver an address at the regular annual meeting, and serve ex officio as a member of the executive committee.

The Vice-President shall preside at business meetings and general sessions of the Society in the absence of the President and serve ex officio as a member of the executive committee.

The Sectional Chairmen shall preside at sectional meetings and serve ex officio as members of the executive committee.

The Secretary-Treasurer shall keep the records of the Society; edit, publish, and distribute the Proceedings and other publications; mail to members a call for papers for the annual meeting at least 30 days prior to closing date for acceptance of papers, and at least 3 months prior to the annual meeting shall request of members suggestions regarding nominations, matters of policy and general welfare of the Society; serve ex officio as a member of the executive and program committees; collect dues from members; and conduct the financial affairs of the Society with the aid and advice of the chairman of the executive committee.

Section 2—*Executive Committee:* There shall be an executive committee consisting of the retiring President, who shall be chairman, the President, the Vice-President, the Sectional Chairmen, the chairmen of regional groups, the Secretary-Treasurer, and two members elected at large for terms of two years each, retiring in alternate years. This committee shall act for the Society in the interim between annual meetings; shall fix the date for the annual meeting; shall present at each annual meeting nominees for members of the nominating committee; shall act on admission of all associate members, regional groups and junior

*As revised and adopted at the Philadelphia meeting, January 1, 1941.

branches and in special cases may elect to voting membership persons of high qualifications but otherwise ineligible; shall consider matters of general policy or welfare of the organization and present its recommendations at the annual meeting of the Society.

Section 3—*Nominating Committee:* There shall be a committee on nominations consisting of two members from each of the sectional groups who shall be nominated by the executive committee and elected by ballot at each annual meeting of the Society. It shall be the duty of this committee, at the following annual meeting to present a list of nominees for the various offices, committees (except the Nominating Committee), representatives, and sectional chairmen who shall be selected after consultation with the sections. This committee shall also nominate referees and alternates upon special subjects of investigation or instruction which may be referred to it for consideration by this Society. The duties of these referees shall be to make concise reports upon recent investigations or methods of teaching in the subjects assigned to them and to report the present status of the same.

Section 4—*Program Committee:* There shall be a committee on program, consisting of five (5) members, of which the secretary shall be one. This committee shall have charge of the scientific activities of the Society, except as otherwise ordered by the Society. It shall receive titles and arrange the program of the annual meeting; arrange symposia; accept or reject titles, and may invite non-members to participate.

Section 5—*Editorial Committee:* There shall be an Editorial Committee consisting of five members. One member shall be elected each year to serve for five years. It shall be the duty of this committee to formulate the editorial and publication policies of the Society; to assist the Secretary in reviewing and editing papers and shall have final authority to reject any paper deemed not worthy or unsuitable for publication in the Proceedings.

Section 6—*Membership Committee:* There shall be a committee on membership whose duties shall be the promotion of membership in the Society.

Section 7—*Auditing Committee:* There shall be a committee to audit the books of the Society and report their condition at each annual meeting.

Section 8—*Committee on Local Arrangements:* There shall be a committee on local arrangements who in cooperation with the Secretary-Treasurer will have charge of all local arrangements for the annual meeting.

Section 9—*Quorum:* Ten members of the Society shall constitute a quorum for the transaction of business at a regularly called meeting of which at least 30 days notice shall have been given to members.

Section 10—*Annual Dues:* The annual dues of the Society shall be five dollars.

Section 11—*Amendment to the By-Laws:* The by-laws may be amended at any regular meeting by a two-thirds vote of members present providing a copy of such amendment has been sent to all members at least 30 days prior to the meeting.

Section 12—*Regional Groups:* Upon the presentation of a petition signed by ten or more members of this Society residing within a stated region, the executive committee may approve the formation of a regional group affiliated with this Society. Such group must elect as a minimum number of officers a chairman, a vice-chairman and a secretary and shall present an annual report to the Secretary-Treasurer of the national Society to include the names of its officials and a review of its meetings or other activities. Publication of this report in full or in part shall be made in the Proceedings of this Society. Papers presented at regional group meetings may be published on the same basis as papers presented at the regular annual meeting.

Section 13—*Junior Branches:* A student horticultural group at a college or university, operating under the supervision of a member or members of this Society, may organize as a Junior Branch of the American Society for Horticultural Science upon approval of the executive committee and the payment of an annual fee of five dollars for the branch. Each branch shall receive a copy of all publications of the Society. Such a branch shall elect a chairman, a vice-chairman and a secretary-treasurer and shall present an annual report of its activities to the national Secretary-Treasurer. Such groups may hold meetings in conjunction with the annual meetings of this Society and a report of such meetings, not including individual papers, may be included in the Proceedings.

SOCIETY AFFAIRS

RESUMÉ OF THE ANNUAL MEETING AT PHILADELPHIA, PENNSYLVANIA, DECEMBER, 30, 31, 1940, AND JANUARY 1, 1941

The thirty-seventh annual meeting of the Society was held in the Engineering Building and Museum Auditorium of the University of Pennsylvania. Society headquarters were the Hotel Normandie.

The subject matter content of the program of the Society and the special sessions held on particular problems are always of interest as indicating the trend of horticultural research throughout the country. This year, on a 3-day program, were four sessions dealing with tree fruit problems; five sessions dealing with vegetable crops, including a joint session with the Potato Association of America; four sessions on floriculture and ornamental horticulture, including a joint session with the American Phytopathological Society; and single sessions on blueberry problems, on small fruits, and on the storage and processing of horticultural products.

The broad interest of the Society and its usefulness in drawing together various groups so as to pool their knowledge and resources upon special crop problems is again indicated by the symposia and joint sessions in which the Society participated. Among these are the joint session on "Present Concepts of Ion Availability in Plant Nutrition", participated in by the American Society of Plant Physiology and the Physiology Section of the Botanical Society of America; and "Theoretical and Practical Aspects of Polyploidy in Crop Plants", in which the Genetics Society of America and the Botanical Society of America joined. In addition, special problems called for round table discussions on educational methods, on nomenclature and varieties in which Dr. Libery Hyde Bailey participated, on experimental design, and on blueberry culture.

The banquet and social evening, which has always been a feature of the Society, was in the hands of the Pennsylvania group of horticultural workers under the chairmanship of Dr. W. B. Mack of Pennsylvania State College, and introduced by Mr. Wister of Philadelphia to tell of the contributions which Philadelphia and Pennsylvania have made to the development of horticulture in America, and provided entertainment by a Pennsylvania Dutch group represented as characteristic of a section of the State.

RESUMÉ OF THE MEETING OF THE WESTERN SECTION

The second annual meeting of the Western Section was held jointly with other groups of the Pacific Division of American Association for Advancement of Science at the University of Washington on June 19, 20, and 21, 1940, followed by a field trip to the Western Washington Experiment Station at Puyallup, Washington, in conjunction with the Northwest Association of Horticulturists, Entomologists, and Plant Pathologists, and the Pacific Division of the American Phytopathological Society. Dr. E. L. Overholser of Washington State College was chairman of the Section for 1939–40, and Dr. W. W. Aldrich of the United States Date Garden, Indio, California, was secretary. New officers elected for 1940–41 were Dr. R. W. Hodgson of Los Angeles, California, chairman; Dr. A. H. Finch of Tucson, Arizona, vice-chairman; and Dr. W. W. Aldrich, Indio, California, secretary-treasurer.

The 1941 meeting will be held at Pasadena, California, June 16 to 21, 1941.

SECRETARY-TREASURER'S REPORT

Membership in the society numbers 732 in good standing, representing a decline of 15 members from last year, due entirely to losses in foreign memberships because of the war. Actually, there has been an increase in membership in the United States.

The money received from dues was $2,988.25, $52.00 less than last year; from the sale of Proceedings $1,232.25, a decrease of $160, the loss in this case also being due to a falling off in foreign orders because of the war. Extra pages purchased by authors amounted to $620.40, an increase of $31.90; and there was also

a substantial increase in income from reprints and etchings, or a total of $2,176.38, representing an increase of $446.32. The total money handled by the society during the year was $12,705.41, an increase of $458.91 from the preceding year.

The society overhead has always been low, considering the activities of the organization and the size of the Proceedings, but by strict economy it was lowered still further this year. Nevertheless, because of the large size of the Proceedings, the society reports a balance of but $4,538.34 on hand, a decline of $887.87 in comparison with the preceding year. This decline is due entirely to the increased cost of the Proceedings, which this year amounted to $5,404.47, an increase of $1,192.51 over last year.

While the society must take cognizance of this increase in the cost of the Proceedings and the lower balance of money on hand, it does not represent a situation which cannot be taken care of. Had the war not been injected into the situation, there is no doubt that the society would have as favorable a balance as in previous years. First of all, it must be remembered that the number of pages printed this last year was 1152 as compared with 874 the previous year, an increase of 278 pages. In analyzing the situation it might be considered that this increase of 278 pages has been responsible for the loss of $887.87 from the previous year's balance. This would be considered a very low per page loss, and could be adjusted very easily by a slight increase in charge per page by the Society, or by a slight increase in membership dues.

It would seem that it would not be difficult to secure the approval of the society to a slight increase in membership dues, or to a slight increase in the cost per page of extra pages, particularly if two volumes a year are published, as at the moment seems a strong possibility. Since the money is on hand already for the publication of the Proceedings of this year's meeting, there is no cause for any thing approaching emergency action, but constructive thought must be given promptly to maintaining the even balance that the society has enjoyed over a period of years.

Treasurer's Report

Receipts

Dues (1940)	$2,988.25		
Proceedings sold (includes bound volumes)	1,232.25		
Extra pages purchased by authors	620.40		
Reprints and etchings sold	2,176.38		
		$7,017.28	
Interest on money in savings account		85.06	
Balance on hand December 18, 1939		5,436.21	
Bills receivable, outstanding accounts		166.86	
			$12,705.41

Expenditures

Expenses of Columbus meeting	$ 67.61		
Expenses of Program committee (1939)	3.68		
Printing Proceedings, Vol. 37	5,404.47		
Programs, letterheads, labels, etc.	163.75		
Reprints	823.62		
Halftones and etchings for Proceedings	701.81		
Secretary's office, including clerical assistance	400.00		
Postage and express, office and shipping Proceedings	294.74		
Stamped envelopes	103.92		
Proceedings purchased for resale	22.00		
Telegram to E. L. Overholser regarding Western Section meeting	1.80		
Exchange on checks during 1940	2.81		
Total Expenditures		$7,990.21	
On hand December 20, 1940		4,548.34	
Bills receivable		166.86	
			$12,705.41

This is to certify that we have examined the books of the Treasurer of this Society and have found them in order.

A. J. WINKLER,
R. A. VAN METER,
Committee

REPORT OF THE EXECUTIVE COMMITTEE AS ADOPTED BY THE SOCIETY

The Executive Committee met at 8:15 p.m. December 29, 1940 at the Normandie Hotel, Philadelphia. Those present were: Messrs. Boswell, Bradford, Haber, MacDaniels, McGinty, Teske, Tukey, and Poesch.

The numerous suggestions and proposals for action submitted to the committee were all given consideration and the following actions taken:

1. The chairman was instructed to pass on to the Nominating Committee those names suggested by members for nominations for the several offices of the Society.

2. The committee recommends that the call for nominations each year shall be accompanied by a list showing the names of the past living presidents, vice-presidents, and secretary-treasurers.

3. The committee recommends that careful attention be given to regional representation as well as subject matter representation among the membership when nominating members for offices and committees.

4. Numerous suggestions submitted to the Executive Committee regarding improvement of the programs were considered. Many of these questions and proposals were also submitted to the committee on program development and are discussed in more detail in that committee report. Briefly, however, the sentiment of the Executive Committee on these are listed here:

(a) The number of symposia scheduled in recent years seems about right to take care of current needs. No marked increase in symposia is recommended now, lest it result in an undesirable restriction or competition for program time with the other features of established value and interest.

(b) The committee recommends against the proposed policy of making up the program solely by invitation papers.

(c) There was a unanimous sentiment in favor of recommending that the present crowded condition of our spoken program be alleviated by alloting a maximum amount of program time to any one member during a single annual meeting. This should encourage each member to present only his best material, thus leaving more time for the best material of other members.

5. The sentiment of the Executive Committee is that publication in two volumes about six months apart seems practicable and is recommended for the consideration of the Society.

6. It was recommended to the Society that an increase in the annual dues from $4.00 to $5.00 be made in order to meet publication expenses in the face of our rather heavy loss in members and sales outside of America.

7. The committee recommended that the two representatives of the Society on the American Association for Advancement of Science council hold that position for six years, one new representative being appointed at three-year intervals. This is to enable representatives to become experienced in the responsibilities they are to have.

8. The committee approved the applications for Junior Memberships submitted by student groups from Purdue University, and A. & M. College of Texas.

9. The committee recommends for appointment to the Nominating Committee for 1941 the following: G. F. Potter, chairman; W. P. Tufts, H. B. Cordner, T. M. Currence, J. C. Ratsek, and S. L. Emsweller.

10. In response to requests from members of the press for the loan of manuscripts, a motion was passed recommending that the secretary should not so release original copies of manuscripts because of the dangers of delay or loss in transit.

Respectfully submitted,
V. R. BOSWELL, *Chairman*

REPORT OF THE NOMINATING COMMITTEE

In its report the Nominating Committee submitted the names of officers and committees as shown on page x of these Proceedings, with the exception of the Nominating Committee, which was nominated by the Executive Committee in accordance with the Constitution. The secretary was instructed to cast the vote of the Society for the officers and committees as nominated, and their election was declared.

REPORT OF THE COMMITTEE ON EDUCATION

The report of the Committee on Education, of which Dr. R. A. Van Meter is chairman, as adopted, will be published in the Proceedings of the Society as a journal article.

REPORT OF THE COMMITTEE ON VARIETIES

The duties of this committee, as set forth in last year's Proceedings, are as follows: "(a) To draw up standard forms for the description of varieties of each of the various fruits that will be suitable for the permanent recording and cataloguing of a variety. (It is now understood that variety descriptions may be filed with the Office of the Division of Vegetable Crops and Diseases of the U. S. Department of Agriculture in Washington, and the L. H. Bailey Hortorium at Ithaca, N. Y.). (b) To decide what plant parts, photographs, or other materials are necessary and desirable for a complete herbarium specimen of a variety in each group of fruits. (Such herbarium materials can be deposited in the L. H. Bailey Hortorium at Ithaca, N. Y. and probably with one of the Federal Departments at Washington, D. C.)"

In line with these two objectives the following Subcommittees were appointed by President L. H. MacDaniels, to work up a descriptive blank for each of the fruits and to make suggestions as to what should be included in permanent "type specimens," material, and new varieties. The leader of each Subcommittee drew freely upon others interested in the particular fruits in question in making up the description blanks. The following were the Chairmen of the different Subcommittees: Professor M. A. Blake, peach; Dr. J. K. Shaw, apple and pear; Mr. G. L. Slate, brambles, currant and gooseberry; Professor R. Wellington, grape; Dr. G. M. Darrow, strawberry; Dr. W. H. Upshall, cherry and plum; Dr. J. H. Clark, blueberry; Dr. G. M. Lawrence, general committee adviser; and Dr. M. J. Dorsey, chairman.

The problem of description, filing "type specimens," registering varieties, and nomenclature was given a general discussion during the Round Table session the evening of December 31, at the Philadelphia meeting. In addition to the subcommittee reports, general session was addressed by Dean Bailey. During the interval after the address those present proceeded to the other section groups and the variety question was then discussed informally by a number of persons including, Professor M. A. Blake, Dr. W. A. Dayton, Mr. W. C. Pyle, Professor W. H. Alderman, Dr. J. K. Shaw, Dr. G. M. Lawrence, Dr. L. H. MacDaniels, and others. In this discussion many phases of the problem at hand were brought out and it seemed desirable to continue the work of these committees for the following year with the following specific objectives in view:

1. To continue work on the descriptive blanks to see how far they could be standardized. In order to meet the requirements of permanent record descriptions these blanks should be submitted to Dr. Lawrence for study and recommendation before publication in the Proceedings.

2. It was informally agreed after the Round Table discussion that type specimens, herbarium material, descriptions, photographs, etcetera, of selected varieties in the different fruits should be worked up and exhibited at the Dallas meeting. It was the thought of the Committee that the descriptive blanks and "type specimens" could very well be made the central theme of next year's Round Table discussion.

M. J. Dorsey, *Chairman*

REPORT OF COMMITTEE TO ASSIST THE NATIONAL RESEARCH COUNCIL IN DEVELOPING A NATIONAL ROSTER OF SCIENTIFIC AND SPECIALIZED PERSONNEL

The committee consisted of the Chairman of the Executive Committee, the President, Vice-President and Secretary.

On June 11, 1940, Dr. R. E. Coker of the Division of Biology and Agriculture of the National Research Council wrote to Dr. E. C. Auchter, advisory representative of our Society with the Council, with reference to our Society giving aid in a nation-wide registration of scientific and technical workers. This letter was referred to the Executive Committee of the Society with the resultant appointment of this committee.

With the concurrence of the other members, the Chairman of the Executive Committee and the Vice-President, who are located near Washington, D. C., called upon representatives of the Council and offered assistance. About October 15 we were asked by representatives of the National Resources Planning Board to provide mailing lists of members and to assist in drawing up a check list to permit the use of sorting machines on the coded data obtained in the registration questionnaires. Both requests were promptly complied with and the committee further supplied a list of all horticultural workers in state and federal research and educational agencies who are not members of this Society.

After a final review of the material passing between the committee and the National Resources Planning Board we received a letter of thanks from the Board dated November 9, 1940, and considered the assignment completed.

Respectfully submitted,
VICTOR R. BOSWELL, *Chairman*
F. C. BRADFORD
L. H. MACDANIELS
H. B. TUKEY

REPORT OF COMMITTEE ON PROGRAM DEVELOPMENT

On February 22, 1940, the President appointed a commmittee "to study the program and to make recommendations in regard to its simplification" as follows: V. R. Boswell, Chairman; J. E. Knott; H. A. Cardinell; C. L. Burkholder; Leon Havis; L. C. Chadwick; J. C. Miller. After exchanges of correspondence involving numerous proposals for improving and increasing the value of the program at the annual meetings, the members of the committee attending the Philadelphia meeting (Messrs. Boswell, Havis, Chadwick and Miller) threshed these questions over at length on December 30, 1940. The committee submits the following recommendations, with comments, for the consideration of the Society:

1. *Recommendation:* Speakers shall be required to observe strictly the time alloted to them on the program.
   Comment: Necessity and desirability are obvious.
2. *Recommendation:* At any annual meeting a member shall be alloted time for only one paper of which he is the sole author; *or* he may be alloted time for not more than two papers of which he is the first-named author.
   Comment: It is believed that this limitation will encourage each member to present only his best and most important material, allowing him more time for presentation and discussion; and also allowing more time for the best that his fellow-members may wish to present.
3. *Recommendation:* The number and magnitude of symposia on the program shall remain approximately as on the programs of recent meetings. Each paper on such symposia as are scheduled shall be organized around and consist chiefly of an original report or exposition, not merely a re-hash or review of literature.

Comment: Despite considerable demand for "more symposia," the committee urges extreme caution in this regard. With general complaint of insufficient time for presentation and discussion of good, new, original work, it appears that more symposia will further encroach on the limited program time available. Furthermore, the main purpose of this Society and its greatest service to horticulture have been the encouragement of original research of ever-increasing calibre, and the provision of a forum where every worker can get the benefits of presenting his problems and results to his fellows. It is considered essential that program time be kept available to the newer and less experienced members as well as to others. In scheduling many symposia there is danger that a disproportionate amount of time will fall to "the older heads" and to reviews of older work thus defeating our major purposes.

4. *Recommendation:* Symposia shall be built up when practicable from titles of original work submitted for presentation at an annual meeting, the subject being determined by the content of the proposed papers. An experienced program committee shall arrange for the suitable expansion of a limited number of papers, and for intercommunication among the proposed speakers beforehand, to insure a well-integrated symposium.
   Comment: This procedure will *not* involve invitation papers. It will depend upon suitability of titles of original work that will be presented anyhow, and is intended as a device to better show the pattern being developed in a given field or subject by the current findings of our members working on related problems.
5. *Recommendation:* As a general policy the program shall consist only of papers reporting original research and submitted at the initiative of the members. So-called "invitation papers" shall not be included.
   Comment: Members having good original material always send in their titles and the Society gets the benefit of their work without asking for it. Invitation papers, papers written "on commission", are, therefore, likely to be largely reviews of older work with which we should be already familiar. The time is already too brief for new original work so should not be used for bringing members up-to-date on their required reading and "home-work".
6. *Recommendation:* In submitting titles for presentation authors shall indicate whether a paper is (a) a preliminary report, (b) a substantial progress report, or (c) a report on a study that has been terminated.
   Comment: This information will enable the program committee to make a more fair and efficient allotment of time for a paper. Generally, preliminary reports deserve the least time because they are incomplete and nonconclusive; substantial progress reports deserve more; and a completed piece of work that the author will not make further reports on deserves the most time—other things being equal.
7. *Recommendation:* Speakers shall use only such slides as are easily read or clearly observed from any position in the room having a clear view of the screen. Slides shall be kept simple and shall include only such pertinent parts of one's data as are essential to illustrate the points made verbally. They need not be replicas of data to be published. Speakers shall carefully guage the amount of material on slides that can be *effectively* presented in the time allowed for exposure of each slide. Leastwise complicated tables should be mimeographed, and complicated or very extensive tables omitted from spoken programs.
   Comment: Disregard of the points covered in the preceding paragraph causes an audience to miss a speaker's points and makes it react adversely to a speaker and his material, even if they are otherwise good.
8. *Recommendation:* The three members on the program committee besides the secretary-treasurer shall each normally serve for three years, one new member of the committee shall be elected each year, and the senior member in point of service shall serve as chairman. They shall make recommendations to the Society regarding improvements in program policy as well as arrange the schedule of papers and group meetings.
   Comment: Some continuity in committee membership is desirable for gaining experience in dealing with program problems and to enable members to develop the best solutions for those problems.

Note: These recommendations and comments apply only to the formal program of the annual meetings, and have no reference to sectional meetings or to publication of papers.

Respectfully submitted,
VICTOR R. BOSWELL, *Chairman*

REPORT OF SPECIAL COMMITTEE APPPOINTED "To Investigate the Possibility of a Journal and to Present the Information to the Members of the Society"

Whereas a study of journals published by similar organizations indicates that such a form of publication would increase our costs and greatly decrease the number of papers published, and

Whereas a majority of your committee and also a majority of other members of the Society who have been contacted seem to prefer our present form of publication (with some modifications) to a journal,

Your committee recommends that for the present the Society continue to publish its reports in the form of "Proceedings".

Your committee further suggests that in order to maintain a more desirable size, the Proceedings be issued in two volumes with the second volume printed late enough to include papers from regional groups whose meetings are held too late to permit publication in the present single volume.

Summary of reasons leading to above recommendations:

1. Cost of publication — a journal would increase our present cost of publication by approximately 50 per cent assuming that we continue to print the same number of pages as in the Proceedings for 1939. This will be apparent if we compare the number of pages published in our Proceedings with the number in three familiar journals put out by organizations whose dues are $5.00 per year as against $4.00 for the American Society for Horticultural Science:

Proceedings, American Society for Horticultural Science 1939	1152 pages
Plant Physiology—1940	785 pages
Phytopathology—1940	1075 pages (approximate)
Journal of American Society of Agronomy—1940	1000 pages (approximate)
Average for the three journals	950 pages (approximate)

(Note—Journals use a more expensive paper than is found in our Proceedings.)

2. A journal is admittedly better than a Proceedings as a medium for the publication of long papers, but if we should change to a journal in which we would publish a fair proportion of long and short articles, it would be impossible to publish all the papers presented at our annual meeting. Plant Physiology during the current year printed a total of 62 articles of varying lengths, plus 24 pages of "Notes". The 1939 Proceedings of the American Society for Horticultural Science printed 250 articles and 21 abstracts. Conceivably, we might use somewhat shorter articles than Plant Physiology and publish from 100 to 125 per year in a journal. Even such maximum numbers would deprive our members of the privilege of publishing more than one-half of the papers included in our last Proceedings or force them to seek other means of publication.
3. Because of war conditions abroad, income from sale of our publication to foreign libraries is almost completely cut off. In view of this fact, and the unsettled situation in the United States, this would seem to be a particularly unfavorable time to undertake the publication of a journal or to assume the added financial responsibilities that would accompany such an undertaking.

W. H. ALDERMAN, *Chairman*
M. B. DAVIS
C. H. CONNORS
J. R. MAGNESS
S. H. YARNELL
H. B. TUKEY
W. H. CHANDLER

REPORT OF THE COMMITTEE ON REVISION OF THE CONSTITUTION AND BY-LAWS AS ADOPTED BY THE SOCIETY

Amendment to Constitution

Article V—Strike out the following words, thereby simplifying the organization by abolishing a non-functioning Council:

> "who, together with the chairmen of the standing committees, shall constitute a Council to act upon all applications for membership".

Revision of By-Laws

Restate Section 1 as follows:

Section 1—*Duties of Officers:* The President shall preside at business meetings and general sessions of the Society, deliver an address at the regular annual meeting, and serve ex officio as a member of the Executive Committee.

The Vice-President shall preside at business meetings and general sessions of the Society in the absence of the President and serve ex officio as a member of the Executive Committee.

The Sectional Chairmen shall preside at sectional meetings and serve ex officio as members of the Executive Committee.

The Secretary-Treasurer shall keep the records of the Society; edit, publish, and distribute the Proceedings and other publications; mail to members a call for papers for the annual meeting at least 30 days prior to closing date for acceptance of papers, and at least 3 months prior to annual meeting shall request of members suggestions regarding nominations, matters of policy and general welfare of the Society; serve ex officio as a member of the Executive and Program Committees; collect dues from members, and conduct the financial affairs of the Society with the aid and advice of the chairman of the Executive Committee.

Restate Section 3 as follows and renumber as Section 2:

Section 2—*Executive Committee:* There shall be an Executive Committee consisting of the retiring President, who shall be chairman, the President, the Vice-President, the Sectional Chairmen, the chairmen of regional groups, the Secretary-Treasurer and two members elected at large for terms of two years each, retiring in alternate years. This committee shall act for the Society in the interim between annual meetings; shall fix the date for the annual meeting; shall present at each annual meeting nominees for members of the Nominating Committee; shall act on admission of all associate members, regional groups and junior branches and in special cases may elect to voting membership persons of high qualifications but otherwise ineligible; shall consider matters of general policy or welfare of the organization and present its recommendations at the annual meeting of the Society.

Combine Sections 2 and 4 and renumber as Section 3.

Section 3—*Nominating Committee:* There shall be a committee on nominations consisting of two members from each of the sectional groups who shall be nominated by the Executive Committee and elected by ballot at each annual meeting of the Society. It shall be the duty of this committee, at the following annual meeting to present a list of nominees for the various offices, committees (except the Nominating Committee), representatives, and sectional chairmen who shall be selected after consultation with the sections. This committee shall also nominate referees and alternates upon special subjects of investigation or instruction which may be referred to it for consideration by this Society. The duties of these referees shall be to make concise reports upon recent investigations or methods of teaching in the subjects assigned to them and to report the present status of the same.

Add at end of Section 5 the following specific duties of the Program Committee, and renumber as Section 4. New material added to this section is in italics.

Section 4—*Program Committee:* There shall be a Committee on Program,

consisting of five (5) members, of which the Secretary shall be one. This committee shall have charge of the scientific activities of the Society, except as otherwise ordered by the Society. *It shall receive titles and arrange the program of the annual meeting; arrange symposia; accept or reject titles and may invite non-members to participate.*

Add at end of Section 8 the following specific duties of the Editorial Committee, and renumber as Section 5. New material added to this section is in italics.

Section 5—*Editorial Committee:* There shall be an Editorial Committee consisting of five members. One member shall be elected each year to serve for five years. *It shall be the duty of this committee to formulate the editorial and publication policies of the Society; to assist the Secretary in reviewing and editing papers and shall have final authority to reject any paper deemed not worthy or unsuitable for publication in the Proceedings.*

Restate Section 9 as follows and renumber as Section 6.

Section 6—*Membership Committee:* There shall be a committee on membership whose duties shall be the promotion of membership in the Society.

Set up the Auditing Committee as a standing committee under Section 7.

Section 7—*Auditing Committee:* There shall be a committee to audit the books of the Society and report their condition at each annual meeting.

Restate Section 10 and renumber as Section 8.

Section 8—*Committee On Local Arrangements:* There shall be a committee on local arrangements who in cooperation with the Secretary-Treasurer will have charge of all local arrangements for the annual meeting.

Restate Section 7 and renumber as Section 9.

Section 9—*Quorum:* Ten members of the Society shall constitute a quorum for the transaction of business at a regularly called meeting of which at least 30 days notice shall have been given to members.

Restate Section 6 and renumber as Section 10.

Section 10—*Annual Dues:* The annual dues of the Society shall be five dollars.

New Section.

Section 11—*Amendment To The By-Laws:* The by-laws may be amended at any regular meeting by a two-thirds vote of members present providing a copy of such amendment has been sent to all members at least 30 days prior to the meeting.

New Section.

Section 12—*Regional Groups:* Upon the presentation of a petition signed by ten or more members of this Society residing within a stated region, the Executive Committee may approve the formation of a regional group affiliated with this Society. Such group must elect as a minimum number of officers a chairman, a vice-chairman and a secretary and shall present an annual report to the Secretary-Treasurer of the national Society to include the names of its officials and a review of its meetings or other activities.

Publication of this report in full or in part shall be made in the Proceedings of this Society. Papers presented at regional group meetings may be published on the same basis as papers presented at the regular annual meeting.

New Section.

Section 13—*Junior Branches:* A student horticultural group at a college or university, operating under the supervision of a member or members of this Society, may organize as a Junior Branch of the American Society for Horticultural Science upon approval of the Executive Committee and the payment of an annual fee of five dollars for the branch. Each branch shall receive a copy of all publications of the Society. Such a branch shall elect a chairman, a vice-chairman and a secretary-treasurer and shall present an annual report of its activities to the national Secretary-Treasurer. Such groups may hold meetings

in conjunction with the annual meetings of this Society and a report of such meetings, not including individual papers, may be included in the Proceedings.

W. H. Alderman, *Chairman*
V. R. Gardner
H. C. Thompson
S. H. Yarnell
H. H. Zimmerley
V. R. Boswell (President) ex officio
H. B. Tukey (Secretary) ex officio

REPORT OF RESOLUTIONS COMMITTEE

Be it resolved, that the American Society for Horticultural Science extend a vote of appreciation to the City of Philadelphia and to the University of Pennsylvania for the fine spirit of cooperation and facilities furnished us for the holding of these meetings.

Resolved, that the Pennsylvania group, especially Dr. W. B. Mack, be extended a vote of thanks for the arrangements made in connection with facilities, rooms, etc. for holding these meetings and for the program in connection with the annual banquet.

Resolved, that the Hotel Normandie be extended a vote of thanks for the facilities furnished and fine spirit of cooperation extended to us as guests in the Hotel.

Resolved, that the American Society for Horticultural Science send a vote of thanks to the American Association for Advancement of Science and especially to Mr. Sam Woodley, for the very satisfactory arrangements and accommodations for the holding of our meeting.

Resolved, that a vote of thanks be extended to the Program Committee, and especially to Dr. F. E. Gardner for the fine program.

E. L. Proebsting, *Chairman*
A. F. Yeager
E. C. Stair

A Response of Apple Trees to Potash in the Champlain Valley of New York

By A. B. Burrell and J. Carlton Cain, *Cornell University, Ithaca, N. Y.*

APPARENTLY there is no report in the literature of correcting leaf scorch of apple by potassium treatments in New York State. Reuther and Boynton (1) showed last year that a low potassium content of apple leaves is associated with leaf scorch in certain New York State orchards and are making further studies. The present study was independent in origin, but utilizes essentially the same methods of leaf-sampling and analysis as described by these workers; the chemical work was done in the same laboratory.

For the past 14 years, leaf scorch and an unthrifty condition of the trees resembling the well-known symptoms of potassium deficiency, have been observed in certain Champlain Valley apple orchards. The symptoms have been fairly common some years on young trees not yet in bearing or on trees just commencing to bear and usually have disappeared as the trees have become older. Frequently the affected trees have been on light soil, on shallow soil, or on soil imperfectly drained, but occasionally they have been growing on the better soils of the region. The degree of severity has been extremely variable from tree to tree and from year to year. Symptoms have been more common under systems of soil management involving cultivation and liberal inorganic nitrogen applications than where manure or hay mulch are used freely. In some cases, these symptoms formerly were complicated by those of boron deficiency, which now has been overcome, facilitating the study of the response to potassium. This report deals exclusively with the variety McIntosh, although the difficulty also has been noted on other varieties.

On the worst untreated trees, the symptoms are expressed in all of the above-ground parts. The whole tree is dwarfed, terminal growth slight, apart from occasional water-sprouts, and twigs are thin. Leaves show marginal scorch, brownish stain, and slight curling; in late summer there is some yellowing and defoliation. Fruits on the branches with severe leaf scorch are small, and tardy in developing red color; if red eventually develops it is dull and purplish instead of bright. No study was made of the condition of the roots.

In previous, unpublished tests, this form of leaf scorch was overcome by keeping the trees under any of the following situations for several years: (a) heavy annual ring of barnyard manure; (b) heavy hay mulch; and (c) serious deficiency of nitrogen whether or not potassium was applied.

Soil Characteristics and Management

The two experiments to be reported were located about one fourth mile apart in a commercial orchard near Peru, Clinton County, New York. The soil is mapped as Coloma fine sandy loam. It is of glacial origin, usually slightly to moderately acid throughout the profile, of

only moderate fertility, and underlaid at depths varying from 4 to 6 feet with unweathered till which limits the depth of root penetration. Sometimes fragments of limestone are found at about the lower limit of root penetration. There is appreciable variation within the area so mapped, in acidity, physical characteristics and crop-supporting ability. Throughout the orchard, 20 per cent superphosphate has been broadcast about once in three years at the rate of 300 pounds per acre. Nitrogen has been used liberally in a ring about the trees. Early-season cultivation has been practiced about one-third of the years; the orchard floor has been covered with grass-clover sod other years. While the cover crop never has been removed, the amount produced has not been large in the experimental areas, and little or no mulch has been brought in from the outside. The land has been farmed for about a century. Occasional clover and alfalfa plants show symptoms closely resembling those published for potassium deficiency.

Experiment I

At the north edge of a block of McIntosh trees set in 1930, there is an area of about ⅓ acre comprising about eight trees in each of three consecutive rows where the trees always have grown poorly. For several years, they have shown abundant leaf scorch and stunted, thin twigs as described in a preceding paragraph. Production has been limited to a few small, pale apples of little or no commercial value. A few of the trees have been judged beyond hope, and replaced. The cover crop is correspondingly poor. Apparently-normal trees with possibly five times the bearing surface surround this area on three sides except for occasional specimens showing variable amounts of leaf scorch. The infertile area extends irregularly into a younger block to the north. The surface soil is a sand of dark color which may at some time in the past, have been poorly drained, though it is not notably so now. The infertile area is near the bottom of a long gentle slope, but the superiority of trees at a still lower level where the soil seems wetter suggests that inadequate drainage is not the decisive factor, if indeed drainage is inadequate.

The general summary of treatments and results is contained in Table I. Four of the worst trees, well distributed in the area of poor soil, were chosen for treatment. Potassium was applied in a trench a foot wide, encircling the tree about 2 feet from the trunk. The bottom of the trench was in contact with apple roots, generally 4 to 8 inches below the surface. The first application, consisting of 3 pounds of sulfate of potash per tree on two trees, and 1½ pounds each of sulfate and muriate of potash on each of the others, was made on May 17, 1939 when the blossom buds were showing pink and commencing to separate from the cluster. The regular fertilizer grades of material were used. There was good rainfall for the next two months, after which a rather severe drouth continued until mid-September. No effects of the treatment were apparent the first year. On June 14, 1940, the treatments were repeated except that 3 pounds of sulfate of potash was applied on each of the four trees. After May 15 there was good rainfall throughout the growing season of 1940.

TABLE I—EFFECT OF POTASSIUM TREATMENTS ON CONDITION AND CHEMICAL COMPOSITION OF MCINTOSH APPLE FOLIAGE (EXPERIMENT I)

Location	Treatment 1939 (Pounds)	Treatment 1940 (Pounds)	Scorch† July 23, 1940 (Per Cent)	General Condition September 20, 1940	Leaf Composition September 18–21, 1940: Ash (Per Cent)	K in Ash (Per Cent)	K in Dry Matter (Per Cent)
I*-71‡-26§	None	None	72.3	—	—	—	—
I -71 -27	None	None	62.1	Scorch severe; some twig growth	7.55	4.36	0.33
I -72 -25	None	None	91.7	—	—	—	—
I -72 -27	None	None	80.8	Scorch severe; some twig growth	6.52	3.88	0.25
I -72 -28	None	None	69.2	Scorch very severe; little growth	5.72	5.22	0.30
I -73 -25	None	None	89.9	—	—	—	—
I -73 -26	None	None	74.5	Scorch severe	6.52	4.14	0.27
I -73 -29	None	None	26.6	—	—	—	—
I -71 -28	$3K_2SO_4$	$3K_2SO_4$	5.2	Good response Scorch on a few twigs	6.78	22.25	1.51
I -72 -26	$3K_2SO_4$	$3K_2SO_4$	5.7	Excellent response	6.78	18.20	1.24
I -72 -29	1½ KCl 1½ K_2SO_4	$3K_2SO_4$	11.7	Excellent response	6.43	15.20	1.10
I -73 -28	1½ KCl 1½ K_2SO_4	$3K_2SO_4$	21.6	Fair response Scorch on several weak branches	6.81	17.94	1.22
O -70 -28	None	None	2.2	Normal	6.81	9.56	0.65
O -72 -30	None	None	Low	Normal	5.96	9.64	0.58
O -74 -27	None	None	Low	Normal	6.75	7.23	0.49
O -74 -28	None	None	1.2	Normal	—	—	—

*I = inside, O = outside infertile area.
†Based on examination of the leaves on 50 spurs per tree.
‡Row number.
§Tree number.

As far as possible, shoot leaves free of scorch were used for chemical analysis. However, on some of the untreated trees it was necessary to use some spur leaves, and some showing scorch in order to have each branch represented in the composite sample of 100 leaves for the tree.

Results:—By July 23, 1940, a conspicuous change had occurred in the treated trees. They had made more growth, the leaves showed a darker green color, and were conspicuously less affected by scorch than in the case of the untreated trees in the infertile area (Table I).

The amount of scorch was not quite as low on the treated trees as on the untreated normal trees just outside the infertile area. This is largely due to the persistence of poor growth and severe scorch on certain branches of the potassium-treated trees. These trees had been sickly for several years and had developed relatively little new wood outside the black-heart that appeared in all apple trees in the region during the severe winter of 1933–34. In some of these branches, the wood has commenced to decay. It is possible that these branches have lost their ability to respond to cultural treatments and must be pruned out.

As shown in Table I, the per cent of ash does not differ greatly from tree to tree and such differences as exist are not correlated with treatment. Since the trends are identical whether the potassium is

based on ash or dry matter, only the latter will be mentioned in the discussion which follows.

The untreated trees within the infertile area are exceptionally low in potassium content ranging from 0.25 to 0.33 per cent, and averaging less than one fourth as much as the four corresponding treated trees. The normal untreated trees outside the infertile area show about twice as much potassium as the untreated trees in the infertile area, but only half as much as the treated trees. All treated trees were in the infertile area. The failure to eliminate scorch completely by a treatment which raised the potassium content of the tree as a whole to the extent indicated, is believed due to the unhealthy condition of the tissues in certain branches, described above. The potassium content of the leaves on these poor, non-responsive branches was not determined separately, but leaves from such branches were included in the composite leaf sample for the whole tree.

Experiment II

This simple trial was started in the spring of 1938 because the trees in this part of the orchard seemed less vigorous than they should have been in consideration of the nitrogen they were receiving; in a very few instances they showed leaf-scorch and staining as described in the introduction to this paper. The trees were set in 1931. While the soil is not highly fertile, it is not conspicuously poor, as was the case in Experiment I. Trees and cover crop had made fair growth.

The treatments, observations on tree responses, and results of chemical analyses are summarized in Table II. All 85 trees in row 29 received liberal applications of potassium and phosphorus in the spring of each of the past three years; details of the treatment appear as a footnote to the table. Around trees 66 to 85 inclusive, half of the fertilizer was applied in five or six shovel-holes about 2 feet from the trunk and 8 inches deep, while the other half was spread in a ring about 8 inches wide between the holes. On the remainder of the row all material was spread on the surface, in a band about 8 inches wide two feet from the tree trunk. The adjacent row on either side served as a check.

Results:—No response to treatment was noted previous to 1940, even where part of the material was applied in holes in contact with tree roots. In the fall of 1940, most rows in this part of the orchard contained four to eight trees showing severe scorch and several others with slight scorch. The only row with no scorch on any tree was the treated row, 29. Two of the most severely scorched trees in row 28, and two in row 30 were chosen for comparison with the nearest comparable tree in row 29. Observations recorded in Table II show that each scorch tree was inferior in fruit size and color to the comparable treated tree. Among these trees showing scorch plus reduction in fruit size and color the potassium content of the leaves was low, the lowest values being for trees with the most severe symptoms. The treatment increased the potassium content by over 200 per cent. Under the conditions of this test, the response to potassium was *not* apparent

TABLE II—EFFECT OF POTASSIUM TREATMENTS ON CONDITION AND CHEMICAL COMPOSITION OF McINTOSH APPLE FOLIAGE AND ON CONDITION OF APPLE FRUITS (EXPERIMENT II)

Location	Treated* or Untreated	General Condition September 21, 1940				Leaf Composition September 21, 1940		
		Set	Fruit Size	Fruit Color	Leaf Scorch	Ash (Per Cent)	K in Ash (Per Cent)	K in Dry Matter (Per Cent)
28‡— 9	Untreated	Good	Small	Pale	Severe	6.96	3.79	0.27
29 — 9	Treated	Good	Large	Good	None	6.85	15.44	1.06
30 —30	Untreated	Good	Medium-small	Fair	Moderate	7.51	5.02	0.38
29 —31	Treated	Fair	Large	Good	None	6.73	17.83	1.21
28 —47	Untreated	Fair	Medium-small	Pale	Slight to moderate	5.90	7.69	0.46
29 —47	Treated	Good	Medium	Good	None	6.65	19.22	1.28
30—58	Untreated	Good	Small	Pale	Moderate to severe	7.07	3.55	0.25
29—58	Treated	Good	Large	Fair to good	None	7.15	11.39	0.82
28 —Composite†	Untreated	Fair to good	Medium to large	Good	None	6.62	9.91	0.66
29 —Composite	Treated	Fair to good	Medium to large	Good	None	6.56	16.09	1.06
30 —Composite	Untreated	Fair to good	Medium to large	Good	None	6.64	8.13	0.54

*Treatments: May 18, 1938: 5 pounds muriate of potash; 5 pounds 32 per cent superphosphate. April 21, 1939: 3 pounds sulfate of potash; 5 pounds 32 per cent superphosphate; May 3, 1940: 2 pounds muriate of potash; 5 pounds 20 per cent superphosphate.

†Each composite sample from about 30 trees was collected October 13, 1940.

‡Row and tree number.

any sooner where the material was placed in holes, than where it was spread on the surface.

The response of the trees is believed due to the potassium rather than to phosphorus applied to the same trees since the symptoms are typical of potassium deficiency, and since they coincide with those in Experiment I, in which the only differences were in the potassium supplied. Whether there was brighter fruit color on the potassium treated row than on the trees without marked scorch in the untreated rows, is uncertain.

The lower part of Table II indicates that the potassium content of shoot leaves from the 30 north McIntosh trees in the treated row was higher than that in either untreated row even though trees showing scorch were omitted in the sampling. Apart from a few scorched trees, the fruit color was good in the north end of each row whether potassium was used or not.

DISCUSSION

Taken as a whole the data presented are considered to show a response of apple trees to potassium. It is not known why the response was not apparent until the second year in Experiment I, and the third year in Experiment II, but such delay seems characteristic of potash experiments with fruit trees (3).

The absolute values for potassium content on untreated trees with and without scorch respectively, are lower than those usually found in the United States (1, 2). Possibly this would be expected for the trees showing scorch in view of the more extreme symptoms described including reduction of fruit size and impairment of fruit color. No effect on fruits was recorded by Reuther and Boynton (2). However, the later date of sampling may account for part of the difference as these workers showed that the potassium content of the leaves may decrease during the summer.

The only positive cases of poor fruit size and color were associated with severe scorching of the leaves. Usually the larger brighter, redder apples were borne on the trees and branches showing little or no scorch, while the smaller, duller greener ones were on branches or spurs showing serious scorch. The active leaf area was cut drastically by the scorch and unthriftiness of these trees and branches. These experiments do not prove whether the inferiority of the fruit was purely a result of decreased leaf area, or whether some more direct effect of potassium deficiency on color also was involved.

The complications that arise from spraying for disease and insect control deserve consideration. This orchard had sprays both of lime sulfur plus lead arsenate and of flotation sulfur plus lead arsenate. Both lime sulfur and the soluble product of the decomposition of lead arsenate are more injurious on devitalized trees, especially if some necrosis already is present. Thus it is possible that the difference in amount of leaf-scorch between the potash-deficient trees and the others may have been exaggerated. However, the potassium deficiency is believed to have been the more important factor because the main symptoms are those well established as due to potassium deficiency and because similar scorch was severe on some little-sprayed young trees adjoining Experiment I. Spray injury does not cause the type of brownish staining mentioned as a symptom of potassium deficiency.

While it is not impossible that the presence of black-heart from winter injury may have been a contributing factor, it is not believed to have been of major importance since numerous young trees not present when the severe winters occurred, and believed to be relatively free of black-heart, showed severe scorch of this type.

Not enough information is yet available for a dependable appraisal of the effect of these treatments on yield.

Conclusion

Although evidence here presented is believed to show that on certain trees potassium treatments improved the general health, greatly reduced leaf scorch, and improved the color and size of fruits, it would be inappropriate to suggest the general use of potash fertilizers in Champlain Valley apple orchards. This 1940 response may or may not be sustained in future years. Furthermore, it was obtained only on rather young trees showing a particular set of symptoms, on soils below average in fertility, and in an orchard where the liberal use of nitrogen and failure to import hay mulch or manure favored the development of potassium deficiency. These specific symptoms are

unusual on trees in full bearing in the region, and are not general in the young orchards. The results were sufficiently clear-cut, however, to justify wider experimentation with potash especially on the younger trees.

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3. Wallace, T. Leaf scorch on fruit trees. *Jour. Pom. and Hort. Sci.* 6: 243. 1928.

Studies with Bitter Pit of the Apple

By Robert M. Smock, *Cornell University, Ithaca, N. Y.*

Abstract

This report will be published in full as a Cornell Memoir.

APPLICATIONS of nitrogen during the growing season to trees at a low level of nitrogen nutrition increased bitter pit susceptibility. These nitrogen applications increased the osmotic concentration of the leaves more than it did that of the fruits. Ringing of limbs after bloom increased susceptibility. Ringing increased the osmotic concentrations of the leaves more than it did that of the fruits. Defoliation of single limbs greatly reduced susceptibility to bitter pit. This treatment removed leaf-fruit competition for water. Partial pedicel girdling increased susceptibility. This treatment increased the osmotic concentration of the leaves at the expense of nearby fruits. Heavy thinning increased susceptibility. This also increased leaf osmotic values more than it did fruit values. Shading of single limbs increased susceptibility. The thesis is presented that bitter pit susceptibility is increased by any field or tree treatment that increases leaf osmotic values at the expense of fruit osmotic values.

Delayed storage hastened the appearance of bitter pit in stored fruit. Controlled atmosphere storage delayed the appearance of bitter pit but did not reduce its final amount. Waxing of fruit prior to storage significantly delayed its appearance. The use of high relative humidities in storage materially delayed or checked the appearance of this trouble on highly susceptible fruit.

Water Culture Experiments on Molybdenum and Copper Deficiencies of Fruit Trees[1]

By D. R. HOAGLAND, *University of California, Berkeley, Calif.*

THE evidence now available that boron, manganese, copper, and zinc are indispensible for the growth of higher plants is so impressive that a reasonable argument might be made that it is no longer worthwhile merely to demonstrate the essentiality of these elements for additional species of plants. With regard to boron and manganese it is probable that this point of view would receive wide acceptance, but some writers still seem to reserve conclusions as to the universality of a requirement of copper and zinc for plant growth. As for molybdenum, evidence of its essentiality for higher plants is recent and restricted to a small number of species, so that experiments on the need for this element by additional species of plants will serve a useful purpose.

Another objective in conducting experiments on copper with fruit tree species is to gain further evidence that the diseases of fruit trees under field conditions which are cured or prevented by applications of copper compounds are in fact copper deficiency diseases. The same question arose earlier in studies of the "little-leaf" disease in its relation to zinc. At first the possibility was envisaged that the beneficial effects of zinc might be due to the neutralization in the soil, or in the tree, of toxic substances generated in the soil. The doubts now seem to be resolved and the disease in question can be referred to as a zinc deficiency disease (without excluding some evidence that microbiological activities in certain soils may lead to disturbance of zinc availability or absorption by the roots). In reaching the present view, controlled water-culture experiments were helpful (4). Symptoms in apricot seedlings very like those of "little-leaf" in fruit trees in the field were produced when zinc was deficient in the nutrient solution. The results of the experiments with apricot seedlings have been confirmed in culture studies with myrobalan plum seedlings.

The present series of experiments was carried on in the seasons of 1938 and 1940. Myrobalan seedlings were grown in nutrient solutions contained in 4 liter pyrex beakers with plaster of paris covers in which the seedlings were supported. These covers were either impregnated with paraffine or coated with asphalt paint. In the latter case the top and sides of the covers also received a coat of aluminum paint. The basic nutrient solution was as follows: $Ca(NO_3)_2$, .005M; KNO_3, .005M; $MgSO_4$, .002M; KH_2PO_4, .001M.

The salts were repurified as described by Stout and Arnon (6), and water redistilled in a pyrex glass still was used. Solutions were changed several times during the season and additional amounts of KNO_3 added when analysis of the solutions indicated that nitrate was near depletion. Purified iron salt was added to the basic solution at frequent intervals and various combinations of other micronutrient elements

[1]Acknowledgment is made of the expert assistance of A. H. Furnstal in conducting these experiments.

initially and whenever solutions were changed. An acid reaction was maintained in the solutions most of the time, usually a little below pH 6, by adding suitable amounts of H_2SO_4 when necessary for adjustment of reactions. Solutions were well aerated by continuous bubbling of air through sintered pyrex glass aerators. The greatest difficulty encountered was in protecting the plants against attacks of red spider. For obvious reasons the use of chemical sprays was not advisable. A considerable measure of control was effected by thoroughly spraying the plants daily with redistilled water.

In the first copper deficiency series, there was added to the basic solution, B, Zn, Mn, Mo, Ti, V, Cr, W, Co, Ni (compare Arnon (2)) with varying amounts of Cu from 0 to 0.1 parts per million (Fig. 1). Definite deficiency symptoms were observed in all cultures except the one to which the highest amount of Cu was added and even in this case there was doubt that the amount of Cu added was optimal. Comparison of plants growing in a parallel series of zinc deficient solutions suggested that the requirement for Cu was higher than that for zinc.

The most characteristic symptom of deficiency was the dying of the twigs from the tip, apparently very similar to the effect described by Oserkowsky and Thomas (3) in the report of their study of exanthema of pear trees in the field. Dwarfing and chlorosis of leaves, with occasional tufting, had some resemblance to effects of zinc deficiency, but the zinc deficient plants did not show the same dying of the shoots. At early stages of growth some copper deficient leaves showed a slight purple tint; later they became pale, but no extreme chlorosis was observed. The experiment of 1940, in which the basic solution was modified to include a small proportion of ammonium nitrogen, gave similar results. The

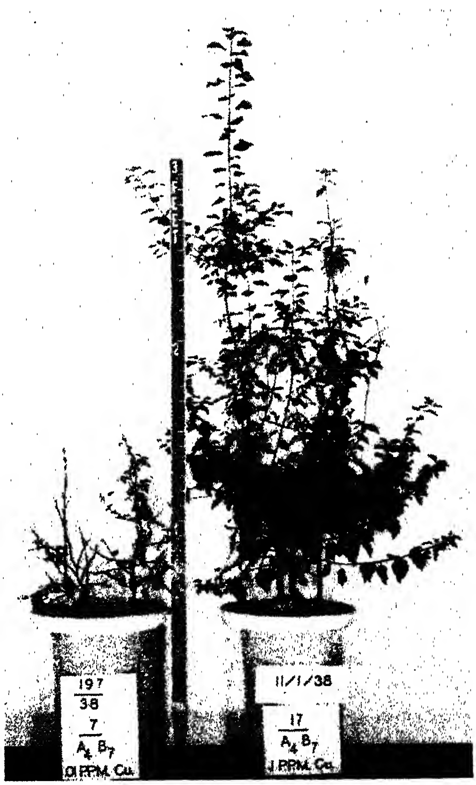

FIG. 1. Comparison of Myrobalan seedlings grown in solutions with 0.01 parts per million Cu and 0.1 parts per million Cu.

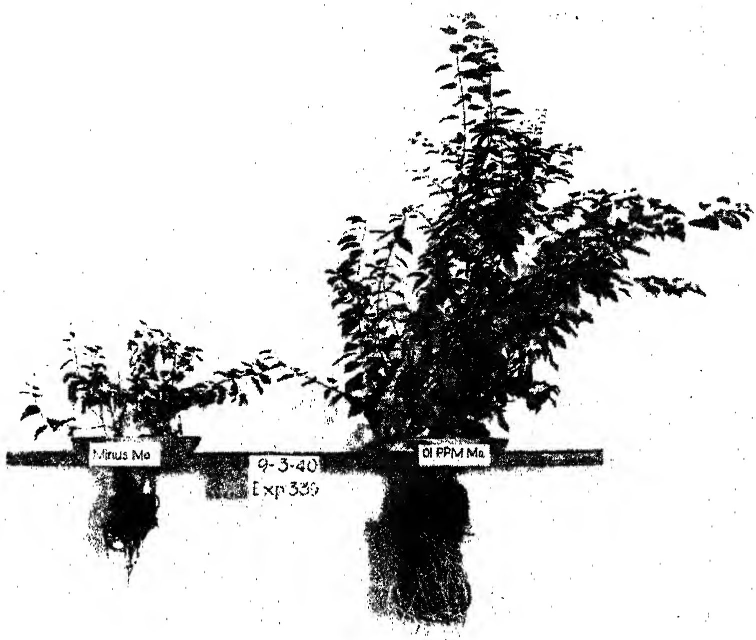

FIG. 2. Illustrating requirement of Mo for normal growth of Myrobalan seedlings. December 15, 1939—stratified seeds; April 1, 1940—planted small seedlings; solution changed one time.

foliage was of good color when 0.2 parts per million of copper was added to the nutrient solution, but 0.05 parts per million was not sufficient to maintain healthy plants. The view expressed by Oserkowsky and Thomas (3) that the exanthema disease studied by them under field conditions is caused by copper deficiency would be supported by the present experiments.

In 1938 an experiment was made to compare solutions containing Cu, B, Mn, Zn (A4, Arnon (2)) with solutions containing Cu, B, Mn, Zn, Mo, Ti, V, Cr, W, Co, Ni, (A4B7, Arnon (2)) and these solutions were compared with two others, one containing minute amounts of eight elements in addition to the A4B7 group and the other 15 additional elements (compare Hoagland and Snyder (5)). The solutions to which either the A4B7 elements or the group of 26 elements were added produced markedly better growth of the seedlings than did the other two solutions. The color of the leaves was also deeper green. One element added to both the superior solutions and not to the others was molybdenum. Meanwhile Arnon and Stout (1) had augmented their evidence that molybdenum is an essential element and in 1940 another experiment was carried out with myrobolan seedlings to make a specific test of this element. (The basic nutrient solution contained a small proportion of ammonium nitrogen).

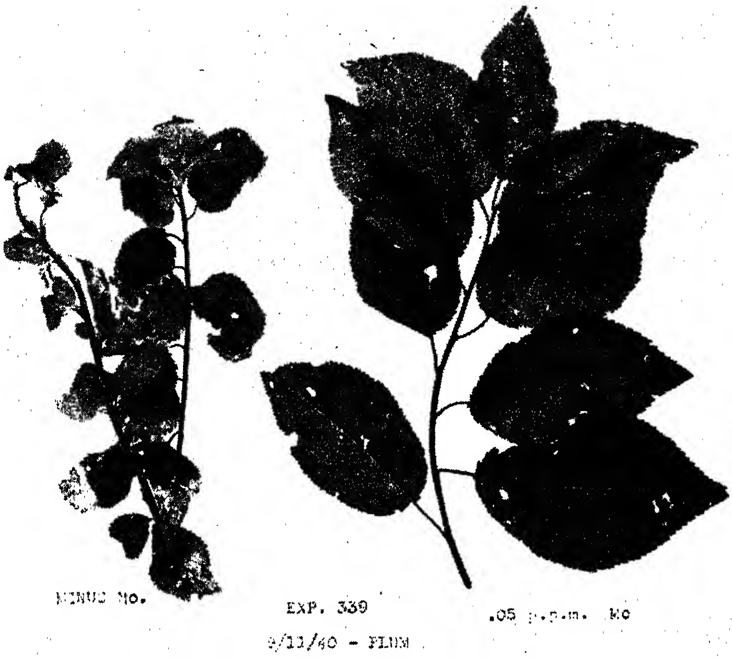

Fig. 3. Showing injury and dwarfing of leaves caused by Mo deficiency.

Five replicate cultures were set up for each treatment with three plants grown in each 4-liter beaker. The effect of molybdenum was of convincing magnitude, despite the large variability of individual plants (Fig. 2). Only one plant out of 15 growing in the minus Mo culture solution failed to show clearly evidence of nutrient deficiency. In plants showing deficiency symptoms leaves were dwarfed; some had a diffuse mottling, apart from insect injury which was present, and many developed light brown areas of dead tissue at tips and margins (Fig. 3). The symptoms of deficiency were distinguishable from those caused by zinc or copper deficiency. Additional evidence is thus provided for the essentiality of molybdenum.

Finally, as a qualitative observation, only suggestive in nature, it was noted in experiments conducted both in 1938 and 1940, that in the latter part of the season, the plants growing in the solution containing 26 elements added to the basic solution appeared superior in growth and in color of leaves, to those growing in solutions with only the five elements, B, Cu, Mn, Bn and Mo added.

In one experiment not now described in detail, made with seedlings from a different source, there was evidence in the latter part of the summer of browning of tips of many leaves of plants growing in the culture containing the five elements mentioned, which was almost absent from plants having access to the larger number of elements derived from the 26 element supplementary solution (B, Cu, Mn, Zn,

Mo, As, Ba, Cd, Bi, Rb, Cr, F, Rb, Hg, Se, Sr, W, V, I, Br, Al, Ti, Sn, Li, Ni, Co). It is true that tomato, lettuce and various other species of plants carefully studied have not so far been demonstrated to have a requirement beyond that of B, Cu, Mn, Zn and Mo, in the list given above, but conclusions with regard to the number of essential elements are only relative to requirements of plants and uncontrolled impurities in the culture solutions. The possibility is not excluded that additional elements may be shown to be essential.

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The Nitrogen, Phosphorus, and Potassium Content of Peach Leaves as Influenced by Soil Treatments

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STUDIES were continued during the past season on the response of peach trees to potassium under field conditions, as determined by foliar analyses. It had been observed that leaves on 5- to 8-year-old trees, previously found by foliar analyses to be low in potassium, were not only smaller in the early part of the growing season than comparable leaves on trees receiving potassium fertilizer but had the color and characteristics of trees low in nitrogen. Since analyses made previously on the trees under study in the field (2) had been concerned with potassium only, it was deemed advisable to study the N-P-K relationship in these trees. Similar studies had been made previously with 1-year-old trees in sand culture in the greenhouse (1).

The trees used in the studies reported here were Elberta peach in their ninth growing season in an orchard at the United States Horticultural Station, Beltsville, Maryland, on a Sassafras gravelly loam soil. These trees had been grown under different systems of soil management for the past 8 years. In late April 1940, crude potassium nitrate containing 13 per cent nitrogen and 43 per cent potassium was applied to alternate or buffer rows of trees which also had had this same treatment in the two previous years, while nitrate of soda alone was applied to all trees in the adjacent rows under a differential cover-crop treatment. The quantity of nitrogen applied to all trees was the same; thus 2¾ pounds of nitrate of soda (16 per cent N) and approximately 3⅓ pounds of potassium nitrate (13 per cent N) were broadcast under the spread of the branches. In addition, 250 pounds per acre of a 5–8–5 fertilizer had been used each season in the tree middles on the spring cover crops and legume sods, and a similar amount used with the winter cover crop of rye and vetch.

Samples of leaves, making up a composite sample of 50 to 75 leaves, were taken from trees in each row. All leaves were full grown with the exception of those taken early in the season. They were collected at four periods during the growing season, taken to the laboratory, and dried and analyzed for total nitrogen, potassium, and phosphorus, using the methods previously described (1). The analyses showing the N-P-K content of these leaves are given in Table I.

RESULTS

It will be noted under the plot treatment (Table I) that potassium was added to all of the even-numbered rows, while the adjacent odd-numbered rows did not receive potassium. There were also two even-numbered plots that received manure but no additional potassium.

The nitrogen values for leaves show no significant differences between plots. Based on the leaf analyses, the trees in all plots that have received equivalent amounts of nitrogen appear to be adequately supplied with this element. Neither cultural treatments nor potassium

TABLE I—FOLIAR N, P, AND K CONTENT OF NINE-YEAR-OLD ELBERTA PEACH TREES IN PERCENTAGE OF DRY WEIGHT

Row	Treatment	June 25			July 31			September 3		
		N	P	K	N	P	K	N	P	K
4	Manure	3.36	0.24	1.69	3.03	0.18	1.31	3.05	0.15	1.19
6	Cultivation +K	3.33	0.22	2.03	3.17	0.18	1.93	3.19	0.16	1.79
7	Cultivation	3.34	0.25	1.02	3.04	0.20	0.86	3.16	0.18	0.98
8	Lespedeza +K	3.11	0.21	2.08	2.93	0.19	2.12	2.96	0.17	1.93
9	Lespedeza	3.08	0.25	0.86	2.79	0.19	0.72	2.84	0.17	0.90
10	Sweet clover +K	3.00	0.22	2.34	2.91	0.21	2.28	2.90	0.17	2.10
11	Sweet clover	3.11	0.24	1.00	3.13	0.21	1.05	2.93	0.17	0.88
12	Soybeans +K	3.33	0.24	2.01	3.20	0.20	2.13	3.23	0.16	1.81
13	Soybeans	3.28	0.25	0.81	3.14	0.16	1.02	3.21	0.15	1.12
14	Buckwheat +K	3.37	0.23	1.79	3.09	0.18	1.57	2.97	0.16	1.65
15	Buckwheat	3.37	0.23	0.67	3.18	0.19	0.71	3.17	0.18	0.74
28	Buckwheat +K	3.80*	0.30*	2.79*	3.20	0.18	2.03	3.24	0.17	1.88
29	Cultivation	3.76*	0.31*	1.62*	3.29	0.23	1.03	3.51	0.21	0.90
34	Manure	3.87*	0.29*	2.26*	2.93	0.17	1.69	3.04	0.18	1.12

*Samples for these analyses were taken May 11.

application seemed to have a significant effect on nitrogen content. The samples of young leaves collected on May 11, about 3 weeks after full bloom, show the highest nitrogen content and there is the usual expected downward trend during the summer, although there is not a marked decrease even in the last sampling, made at harvest time. The two legume sod plots show lower nitrogen leaf content after midsummer, but these differences are not significant.

In contrast to the nitrogen, the potassium content of the leaves shows a very significant difference between rows. Leaves from all trees receiving potassium, regardless of management or cover-crop treatment, have in most cases twice the potassium content of the trees not receiving this element. The highest K leaf content of the latter trees is slightly over 1 per cent and on two plots, 9 and 15, the values at no time during the season were above 0.90 per cent. It has been shown with young peach trees (2) that a K leaf content below 0.90 is usually associated with marked symptoms of potassium deficiency. The only symptoms of this deficiency on the bearing trees here studied were that the leaves were smaller and slightly lighter in color on trees low in potassium. Leaves of trees in the manure plot were not as high in K content as those receiving potassium nitrate, but were of good size and color, indicating an adequate supply of K.

The K value for the samples taken at three different periods shows a slight trend downward as the season advances. This has also been observed by Lilleland and Brown (3). The downward trend is shown more clearly where samples taken early in the season are compared with those taken later, as in plots 28 to 34 in Table I. These seasonal changes appear to be greatest with trees having the higher K content. This might be expected because of variation between trees high in potassium, while there would be less variation in the leaf content of trees growing at a low level of potassium. The effect of cultural treatment on K content does not seem to be significant.

The phosphorus values, like those of nitrogen, do not show marked differences between plots and no significant relationship to potassium. The relative amounts in the leaves indicate an adequate supply for

the needs of the tree and are comparable to the quantities found in the leaves of young peach trees making good growth in nutrient solution containing 10 to 20 parts per million of P (1). The phosphorus content of the leaves shows a significant downward trend as the season advances.

Since plots 6 to 15 were suitable for statistical treatment, an analysis of variance was made on these plots. The results of analysis of this part of the data agree with the conclusions drawn from direct inspection of the entire data.

The difference in growth rate and final size of the leaves of these bearing peach trees appears to be due to the low potassium reserve in the trees when growth was initiated in the spring. No studies were made to determine what effect the low potassium had on carbohydrate synthesis. However, it was apparent from growth records that the trees adequately supplied with potassium had a much greater leaf area, made greater total growth, and formed a larger number of blossom buds to a linear foot of terminal shoot growth. Fruit production, while influenced by plot treatment, was relatively higher on the adjacent plots receiving a potassium salt.

Seasonal Uptake of Potassium by Low K Trees

In order to determine the rate of potassium intake as measured by changes in the leaf content during the season, applications were made to 4- and 8-year-old trees after growth had started in the spring of 1940. The trees selected were paired according to size. Potassium sulphate was used as a source of potassium at the rate of 3 pounds for 8-year-old trees and 2 pounds for 4-year-old ones. Nitrate of soda was used as a source of nitrogen for all trees. The nitrate was broadcast, while the potassium sulphate was spread in a similar manner in a surface application at two different periods: 10 days after full bloom (May 10) on the 8-year-old trees, and 42 days after full bloom (June 12) on the 4-year-old trees. The application made on May 10 was followed by a light rain, and a heavy rain occurred 6 days later. No rain fell after the June 12 application until 13 days later. Changes in the K content of the leaves as the season progressed are shown in Table II.

There was apparently no significant difference in the K content of leaves of 4-year-old trees 2 weeks after application. This might be expected, since no rainfall had occurred between the time of application and the date of sampling. However, 7 weeks later the leaves of trees

TABLE II—Changes in K Leaf Content From One Application (1940)

Tree	Age (Yrs.)	Treatment	Per Cent Potassium in Leaves (Dry-Weight Basis)			
			May 10	June 25	July 31	September 3
27–1	4	No potassium..............	....	0.86	0.62	0.43
27–2	4	2 pounds K_2SO_4 June 12, 1940.	....	.71	1.96	1.96
29–4	8	3 pounds K_2SO_4 May 10, 1940.	1.07	1.10	2.20	2.20
29–5	8	No potassium..............	1.03	.84	0.62	.50

receiving potassium showed three times as much potassium as the check and by September 3, four times that of the check. Similarly, leaves of the 8-year-old trees receiving potassium May 10 showed a significantly greater K content than the check, having by July 31 and September 3 three and four times, respectively, the K content of the leaves of the check tree. It will also be noted that the potassium content of leaves of trees receiving this element for only one season was almost as great at the time of fruit harvest (September 3) as that of trees receiving this element for 3 years.

Discussion

It is apparent that bearing peach trees growing in a soil with low available potassium may not show marked symptoms of potassium deficiency. This would be true under conditions when sufficient amounts of this element were available for growth but not adequate for optimum tree functioning. It is not known in the experiments reported here what percentage of the potassium in the salts applied to the soil was fixed. It is clear that the potassium content of the leaves was increased to three to four times that of unfertilized trees by surface application of 1.25 pounds of potassium to the soil. It is also not known whether a potassium reserve has been restored to the soil complex or whether further soil applications would be required annually to maintain available potassium to satisfy tree growth and maintain production. During the 3 years that potassium has been supplied there is no indication from the leaf analyses that there has been an increase in the build-up of K reserves in the tree. It is interesting to note that the trees receiving manure for an 8-year period show somewhat intermediate values between the trees receiving no potassium and those supplied with potassium salts. The slightly lower values for the manure plots may not be significant in view of the fact that they are the heaviest in production.

In these bearing trees lack of potassium has significantly affected leaf size. This was readily apparent when adjacent treated and non-treated rows were compared. Symptoms of potassium deficiency were otherwise not clearly discernible, although there was a marked difference in potassium content of the leaves as determined by chemical analyses.

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Leaf Analysis and Apparent Response to Potassium in Some Prune and Apple Orchards, Preliminary Report

By Damon Boynton, Walter Reuther, and J. C. Cain,
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IN THE course of a study of the potassium level of fruit trees growing on some important New York orchard soils (2), there were encountered instances of "leaf scorch" associated with very low potassium content of foliage. This paper is a preliminary report on the effect of potassium fertilization on leaf analysis and severity of leaf scorch symptoms in four prune orchards and two apple orchards whose trees were initially low in potassium and showed varying degrees of leaf scorch.

Symptoms of Leaf Scorch in New York

The general symptoms in New York prune and apple orchards seem to be similar to those described by Wallace (3). Leaves of affected Italian prune trees appear normal in spring and early summer. By mid-July leaves on some peripheral branches may begin to lose normal green color, usually fading first at the margins. As chlorosis progresses, the margins of older shoot leaves roll inward toward the upper surface. Finally, marginal necrosis appears (Fig. 1). On severely affected trees, almost all the leaves may show progressive development of these symptoms. On moderately affected trees only the older leaves on peripheral branches may develop all stages of the symptoms. On slightly affected

Fig. 1. Italian Prune branches from orchard showing scorch. Left to right: severely affected, moderately affected, normal.

FIG. 2. Rhode Island Greening apple branches from orchard showing scorch. Left, scorched, right, normal.

trees, the symptoms may develop late, on outer branches only, and may not proceed beyond the "leaf roll" stage. The cumulative effects of severe scorch are decreased terminal growth, delayed fruiting of young trees, and marked dwarfness. Within an orchard on apparently uniform soil there may be marked differences in degree of scorching among the trees.

The general symptoms are the same on apple trees. However affected leaves of variety Rhode Island Greening tend to fold at the midrib toward the upper surface rather than to roll (Fig. 2). Leaves of variety McIntosh do not seem to fold or roll until after there is rather severe marginal necrosis; the midribs of affected McIntosh leaves seem to be more reflexed than those of normal leaves.

METHODS

In 1939, tests of response to potassium fertilization were begun in two 6-year-old Italian prune blocks which showed severe scorch the previous year. In 1940 the tests were continued. Those results, together with results of tests on two other prune blocks and in two apple blocks, made in 1940, are summarized in Table I.

In the five orchards listed first in Table I, from nine to 20 groups of two or three adjacent trees were selected for uniformity of size and degree of scorch previously exhibited. Within each group the trees were treated as stated in the table. The treatments in the sixth orchard (orchard M) were made to adjacent rows of 12 trees.

Observations on development of symptoms were made about once a month during 1939 and 1940, and the severity of scorching on each tree was recorded twice during both summers. Composite leaf samples were taken for analysis from the trees of each plot twice during each growing season. Where it was possible, uninjured leaves of normal appearance were sampled. In no case were leaves showing more than 5 per cent necrosis used. Typical data are presented in Table I.

DISCUSSION

Table I shows the relationship between treatment with potassium

salts or manure, percentage potassium in the leaf samples, and apparent decrease of leaf scorch in these prune and apple orchards. There was less scorch and less severe scorch on trees fertilized with potassium or manure than on similar unfertilized trees. In all of the orchards, the percentage of potassium in the foliage seemed to be materially increased by application of K_2SO_4 or KCl to the surface of the soil. In any one orchard the leaf percentage of potassium was proportional

TABLE I—POTASSIUM CONTENT OF LEAVES AND SEVERITY OF LEAF SCORCH ON SOME PRUNE AND APPLE TREES DIFFERENTIALLY FERTILIZED WITH POTASSIUM SALTS, 1939 AND 1940

Year	Treatment*	Potassium Content of Leaves**		Foliage Symptons in Late Summer§		
		Date Sampled	K in Dry Matter (Per Cent)	Number Trees Showing Symptoms		
				O-Trace	Mild	Severe
	H. 6-Year-Old Italian Prunes on Berrien Fine Sandy Loam, Cultivated					
1939	A 1 pound K_2SO_4 (40 per cent)	Sep 26‡	1.56	12	7	1
	B 3 pounds K_2SO_4		1.81	15	5	0
	C Check		0.73	8	6	6
1940	A 1 pound K Cl (60 per cent)	Aug 15‡	1.86	9	8	3
	B 3 pounds K Cl		2.20	12	7	1
	C Check		1.13	2	7	11
	T1. 6-Year-Old Italian Prunes on Collamer Silt Loam, Cultivated. Heavily Manured in May, 1939					
1939	A 1 pound K_2SO_4	Sep 25‡	—	11	1	0
	B 3 pounds K_2SO_4		2.46	12	0	0
	C Check		1.59	9	2	1
1940	A 1 pound K Cl	Aug 14	1.97	10	2	0
	B 3 pounds K Cl		2.12	12	0	0
	C Check		0.90	3	8	1
	T2. 4-Year-Old Italian Prunes on Dunkirk Gravelly Loam, Cultivated					
1940	A 1 pound K Cl	Aug 14	1.14	5	4	3
	B 2 pounds K Cl		1.45	6	6	0
	C Check		0.98	1	3	8
	B. 10-Year-Old Italian Prunes on Granby Loamy, Fine Sand, Cultivated					
1940	A 4 pounds K Cl	Sep 17	2.31	3	6	0
	C Check		0.76	0	1	8
	G. 12-Year-Old R. I. Greening Apples on Worth Loam, Sod + $NaNO_3$					
1940	A 5 pounds + 3 pounds K Cl†	Aug 16‡	1.32	7	3	0
	C Check		0.47	0	2	8
	M. 3-Year-Old McIntosh Apples on Dutchess Gravelly Loam, Cultivated					
1940	A 1 pound K Cl	Aug 27	0.67	8	1	3
	C_1 Check		0.36***	1	4	7
	B 2 pounds K Cl		0.85	10	1	1
	C_2 Check		0.36***	2	4	6
	M Heavy manure mulch		1.15	9	3	0
	C_3 Check		0.36***	4	3	5

*All fertilizer was broadcast in a fairly concentrated ring under the spread of the branches. Application was made in April unless otherwise noted.

**Samples consisted of 100 leaves, none of which showed more than 5 per cent necrosis. The samples were composited from leaves, selected at random locations on all the trees in a treatment in median positions on shoots, one leaf per shoot. They were dried to constant weight at 65 degrees C. The analyses were made by Hibbard and Stout 1933 method, expressed as elemental K.

‡Similar samples taken in these plots at earlier dates of 1939 and 1940 were very close in analysis to the figures presented here.

§Scorings were made in mid-summer and again in late summer on the basis of the severity of rolling or folding of the leaves and marginal necrosis of the leaves. Scorings were made independently by at least two observers.

†5 pounds K Cl was applied in April; 3 pounds K Cl was applied in June.

***Analysis of single composite leaf sample from rows C_1, C_2, and C_3.

to the amount of fertilizer applied to the soil. Fixation did not seem to have prevented the movement of some of the applied potassium into the trees.

The heavy manure application in May, 1939, to all trees of Orchard T1, seemed to have increased the percentage of K in the leaves and to have decreased the amount of scorch. This is indicated by the fact that the potassium percentage in the check and B group leaf samples were lower in 1940 than in 1939 a few months after the application, and by the fact that the check trees showed much more leaf roll and chlorosis in 1940 than in 1939. The effectiveness of manure in raising the potassium level of foliage is also apparent in the data from orchard M where the highest leaf potassium level was in the manured row. The trees in that row showed less scorch than in any other row except the one fertilized with two pounds of KCl. This and some unpublished data support the conclusion of Wallace (3) and others that manure is a very effective source of potash for fruit trees.

While there seems to have been a reduction in scorch as a result of potassium application, the only instance of a complete disappearance of symptoms occurred in the case of the B group trees of orchard T1 which received a heavy manure mulch in 1939 as well as 3 pounds of potassium fertilizer annually. Whether or not the failure to cure scorch completely is due to a lag in the effectiveness of potash, like that found by Wallace (3), remains to be seen. Assuming that the partial effectiveness is due to lag, it seems likely that the lag is due to conditions within the tree rather than to unavailability of applied potassium. Thus even when the potassium level of the leaves in the B group trees of orchard H was raised to 2.2 per cent, eight of 20 trees showed some symptoms of scorch.

The data of Table I, confirm the work of Lilleland and Brown (1) which indicates that the potassium content of prune leaves is normally above that of apple leaves, and that prune trees frequently show symptoms of scorch when the potassium content of the leaves drops below 2 per cent of dry weight. On the other hand, the apparent response of the apple trees in orchards G and M to potassium fertilization was accompanied by an increase in leaf potassium to a point within the range of 0.75 to 1.00 per cent of dry weight suggested by Reuther and Boynton (2) as a minimum range below which McIntosh apple trees frequently show scorch.

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The Relation of Peach Root Toxicity to the Re-establishing of Peach Orchards

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THE replanting of the same species of trees following the removal of an orchard has been recognized for many years as a hazardous undertaking. While some instances of complete success are known, a high percentage of unsatisfactory orchards is produced. The problem has become acute in certain California peach districts where large acreages are approaching senescence. A study of the problem was undertaken in 1937.

A study of the literature revealed a number of reports of the condition, but yielded little information on diagnosis or control. Apples, cherries and peaches have received particular attention and apricots and prunes a lesser amount. Johansson (1) reported the use of various soil sterilizing agents, but success followed only the use of formaldehyde. The New Jersey Station (3) seemed to have success with increased moisture in the B horizon and increased nutrient level, in replanted peach orchards. Wallace (5) found correction of nitrogen and potassium deficiencies to be insufficient in certain areas, and attributes the poor results to continued cultivation, with unsatisfactory physical condition of the soil a major factor. Verner (4) considered spray residues, specifically arsenic, to be a factor. Klaus (2) has summarized the literature, especially the German, in a recent paper.

A survey of the important peach districts in California indicated varying success of replanted orchards, from complete success to failure of a considerable proportion of the trees to grow. A typical difference in growth of peach trees is shown in Fig. 1. These differences of behavior could not be correlated with climate, soil texture or obvious cultural practices.

Experimental work was then started on the following hypotheses: (a) depletion of common nutrients, either by the preceding orchard or by soil organisms using root residues as a source of energy; (b) minor element deficiencies; (c) diseases developed on the initial planting and carried over to the next; and (e) direct toxicity of the roots or their decomposition products.

FIG. 1. Two-year-old peach trees; left, in soil which has never grown peaches; right, replanted after peaches.

Several fertilizer plots were laid out in districts where this trouble was common. Ammonium

sulfate was applied at rates varying from 1/4 pound, placed in the hole at planting, to 20 pounds well distributed around the tree on the soil surface. Responses were obtained in some orchards, where there was nitrogen deficiency, but the basic difficulty was not overcome. Amounts of potassium up to 10 pounds K_2SO_4 applied in various ways failed to give response. A few reports of response to bone meal in the holes were received, but even as much as 10 pounds of treble superphosphate produced no response in our trials.

The use of Mn, Zn and Cu failed to stimulate growth. Trials of vitamin B_1, indole-butyric acid and indole-propionic acid in various amounts and combinations also were without benefit. Peat moss was beneficial in some cases.

While disease, particularly crown gall (*Pseudomonas tumefaciens*) and oak rot fungus (*Armillarea mellea*), may be an important factor in the failure of certain replanted orchards, it by no means covers the case. The Division of Plant Pathology has reported as free from parasites specimens obtained from replanted orchards of sub-normal development.

These facts seem to relegate nutrition and disease to minor roles in the situation. The fourth hypothesis has been more productive.

A comparison was made between peach seedlings grown in the greenhouse in 5 gallon cans of screened soil from a peach orchard in Sutter County exhibiting the trouble and from adjacent land not previously in peaches. No significant differences in growth were obtained. When 500 grams of peach roots were added to virgin soil, however, in similar containers, the following results were obtained: the total average shoot length per check tree was 481 centimeters, per treated tree 326 centimeters. The respective average weights were: check, 102.5 grams; treated, 53.7 grams. The treated trees appeared normal in every respect except size.

Another series of peach seedlings was planted in 3 gallon containers with soil plus roots of cherry, of apricot or of myrobalan in order to determine whether other stone fruits affected peach trees in the same manner. Average total shoot growth after growth had ceased was as follows: check, 206 centimeters per tree; as compared to 81, 109 and 127 centimeters, respectively, when cherry, apricot and myrobalan roots were added to the soil. The effect of all of these roots was to reduce the growth of laterals rather than of the main stem.

Conversely, almond, apricot and myrobalan seedlings were planted in the field where peaches had been removed, with peaches as checks. The unbudded seedlings of myrobalan made very strong growth, and those of almond and apricot, satisfactory growth. The common peach seedlings were generally unsatisfactory. Vigorous oriental peach stocks (Shalil, Bokhara and Yunnan) are being tried, with good results, as seedlings. Budded material was also tried but is not far enough along to report. Some of the seedlings were budded to peaches, but as almond, apricot and myrobalan are not dependable stocks for peaches, the resulting growth was uneven.

An apricot orchard planted, following the removal of a 40-year-old peach orchard, made up of alternating rows on apricot and peach root,

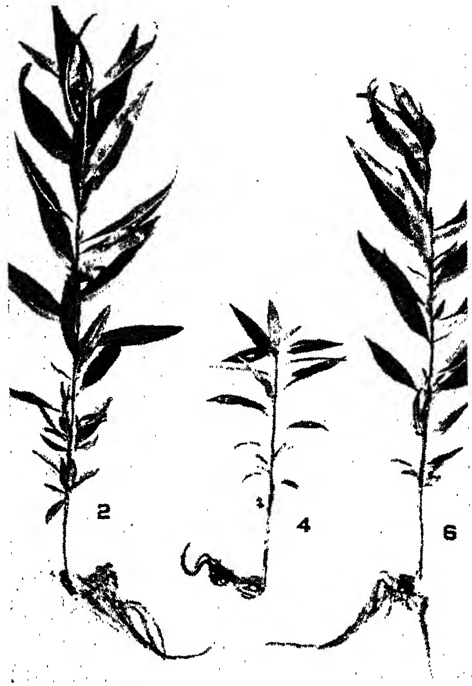

FIG. 2. Peach seedlings grown in sand culture. No. 2, check; No. 4, 20 grams of root bark; No. 6, 20 grams of root wood.

showed strikingly greater growth on apricot. Normally, peach root gives a tree of as great vigor. The average circumference of 360 trees on peach was 46.9 centimeters and of an equal number on apricot, 52.3 centimeters at 9 years of age. This shows the persistence of the effect into maturity.

Having found that peach root residues were effective in reducing growth, bark and wood of peach roots were separated, dried, and after grinding were added in varying amounts to cultures of peach seedlings. In one set of experiments bark or wood from the roots were added in 10- and 20-gram portions, distributed just above the root area and around the stem, to uniform seedlings in 3 gallon sand cultures. In most cases 10 grams of bark applied in this way was sufficient to kill the seedling in 4 to 5 days. Occasionally, however, death did not follow the application but growth was stopped. Fig. 2 shows the condition of one set of trees 27 days after treatment. No. 4, which had 20 grams of root bark, made no growth following the treatment, in contrast to No. 6, which had 20 grams of wood, and No. 2, the untreated check.

Another series of sand cultures was set up using peach seedlings in 6-inch flower pots, six plants being used for each treatment. The treatments in this series were as follows:

1. Check.
2. Root bark; 5 grams of dried, ground peach root bark well mixed with the sand at the time of potting; 10 grams more added in the same way to three trees on re-potting 34 days later; 20 grams added to the remaining three trees.
3. Root bark plus peat moss; the same as 2 except for the addition of 5 grams peat moss, also mixed with the sand.
4. Root wood; the same quantities and method of application as above, in 2.
5. Alcoholic extract of root bark; this material was added as a dry

substance in an amount equivalent to 5 grams bark for the first application; and equivalent to 10 grams for three trees, 20 grams for three trees for the second application, as in 2.

6. Root bark residue after alcohol extraction; the same as 5.
7. Water extract of root bark; an amount equivalent to 5 grams added with the nutrient solution each week during the first 34 day period; then the amount equivalent to 10 grams added each week to three trees; 20 grams to remaining three trees.
8. Root bark residue after water extraction; the same as 5.

A complete nutrient solution was supplied to all of the treatments. The check trees were also re-potted at the same time as the treated trees.

The increased rate of application made after 34 days was given because of the lack of observable differences at that time. This behavior is in contrast to that of the series referred to above where the root bark applied at or near the surface resulted in the death of most of the seedlings. After 36 days at the higher rates of application the experiment was concluded. Table I gives the order of severity of injury to the tops. One indicates no injury; seven, the most severe injury.

TABLE I—INJURY TO TOP GROWTH FOLLOWING APPLICATIONS OF ROOT SUBSTANCES

Treatment	Order of Injury
Check	1
Root bark after alcohol extraction; equivalent to 10 to 20 grams	1
Water extract of root bark; equivalent to 10 to 20 grams per week	2
Root bark after water extraction; equivalent to 10 to 20 grams	3
Root wood; 10 to 20 grams	4
Alcohol extract of root bark; equivalent to 10 to 20 grams	5
Root bark; 10 to 20 grams	6
Root bark, 10 to 20 grams+5 grams peat moss	7

At the conclusion of the experiment the root systems were examined and injury was found to have been greater than would have been expected by examination of the tops. In many cases severe injury had resulted, followed by regeneration. The fact that regeneration occurred would seem to indicate that the toxic effect did not endure for any length of time in the sand cultures. This short duration of the injurious effect may have been due to leaching, which was indicated by the high color of the effluent from the cultures for several days after treatment. The greater injury in the series with peat moss added may be due to a reduction in the rate of leaching.

The order of severity of root injury is shown in Table II.

TABLE II—INJURY TO ROOTS FOLLOWING APPLICATIONS OF ROOT SUBSTANCES

Treatment	Order of Injury
Check	1
Root bark after alcohol extraction; equivalent to 10 to 20 grams	1
Root bark after water extraction; equivalent to 10 to 20 grams	2
Root wood; 10 to 20 grams	3
Root bark; 10 to 20 grams	3
Water extract of root bark; equivalent to 10 to 20 gram sper week	4
Alcohol extract of root bark; equivalent to 10 to 20 grams	5
Bark, 10 to 20 grams+5 grams peat moss	5

These experiments are now being re-run to determine whether the injury is greater in a typical orchard soil than in sand culture.

The following conclusions may be drawn from the data presented in the preceding tables: (a) that the application of root bark produced injury to top and root of peach seedlings; (b) that the alcohol extract of root bark also produced injury, and (c) the bark residue after the alcohol extraction was harmless.

The alcohol extract which retains some of the injurious properties of the bark has been fractionated and tested but these tests have not shown strong indications that the toxic properties were retained by any of the fractions.

Peach root bark when heated with water gives off the odor of benzaldehyde which we have assumed indicates the presence of amygdalin. Experiments in which 1 gram of amygdalin was added to 250 cubic centimeters of nutrient and applied once or twice a week to trees in sand showed no injury and in some cases these trees were superior to their checks. If, however, amygdalin was applied as described along with a trace of emulsin, injury was severe. Two treatments 3 days apart were sufficient to cause the death of the seedlings in 30 to 40 days after the first treatment. Emulsin alone proved harmless. Dextrose produced some retardation of growth.

Benzaldehyde and potassium cyanide were applied in amounts ranging up to 1 gram of benzaldehyde per week in two treatments and 1/10 gram of potassium cyanide once a week. The benzaldehyde, which was applied by shaking into an emulsion with the nutrient had little effect. The cyanide showed little injury at a rate of 1/20 gram per week in single application but the 1/10 gram dosage produced severe injury. The trees showed signs of recovery after cessation of the cyanide treatment, though they did not after the amygdalin emulsin treatments which contained the same amount of CN as the heaviest KCN applications. Tannic acid was also applied in the nutrient solution at rates up to 1½ grams per week. There was no injury and in some instances the trees treated with tannic acid were more vigorous than any others, including the checks.

Summary of Results

A field survey has shown that a high percentage of replanted peach orchards fails to make normal growth. It has been found that exhaustion of plant nutrients or diseases carried over from the preceding planting are not adequate explanations. Peach roots added to virgin soil inhibited growth of peach seedlings. In sand culture, the root bark was found to be toxic, but not the wood. The alcohol extract of bark also was toxic, while the residue from alcohol extraction was not. The specific compounds concerned have not yet been identified.

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Potassium Translocation in Peach Roots

By O. W. DAVIDSON, *N. J. Agricultural Experiment Station, New Brunswick, N. J.*

ABSTRACT

This paper will be published in full in *Soil Science.*

POTASSIUM translocation studies were conducted with peach roots during the summers of 1938 and 1939. The roots of 1-year-old nursery peach trees were divided horizontally into upper and lower tiers. Rootlets were selected in such a manner that one in the lower tier was paired with one of similar size directly above it in the upper tier. Four or more roots were selected in each tier, and all others were removed. The trees were placed in especially constructed, double-chambered sand cultures. These cultures allowed the roots of the lower tier to pass through a glass tube sealed into the center of the top chamber and thus extend into the bottom chamber, while those of the upper tier remained in the top chamber.

All plants were supplied with a potassium-free nutrient solution until symptoms of severe potassium deficiency developed. At that time the plants were divided as follows: Series I received potassium in the top chamber and a potassium-free solution in the bottom. Series II received a potassium-free solution in the top chamber and a plus potassium solution in the bottom. Series III was maintained on a potassium-free treatment in both chambers.

Plants were harvested 5, 13, and 43 days after applying potassium to one of the chambers. The results of analyses on samples comprised of fleshy and fibrous roots less than 1/16 inch in diameter showed conclusively that potassium is readily translocated from upper to lower roots, and likewise from lower to upper roots.

The Response of McIntosh Apple Trees to Improved Sub-Soil Aeration

By A. J. HEINICKE and DAMON BOYNTON, *Cornell University, Ithaca, N. Y.*

THE specific soil factors responsible for marked variations in tree growth and productivity on two plots of McIntosh apple trees of the same age in the Cornell University orchard at Ithaca, New York, have been under investigation for a number of years (1, 2, 4, 5). Recent work has suggested that the relatively poor tree performance may be due primarily to poor soil aeration that exists even after all gravitational water has been removed by ordinary tile drainage (2, 4). The following experiment was designed to determine whether improved aeration of a soil that was previously unsatisfactory for tree growth would overcome the difficulties.

MATERIALS AND METHODS

In the summer of 1938 two plots 40 by 40 feet in size which had been occupied for 25 years by McIntosh apple trees of relatively low vigor were set aside for the experiment. The plots were on the same soil type, a heavy phase of Dunkirk silty clay loam, and were located within 100 feet of each other on approximately the same level. An ordinary tile drain which passed within 10 feet of the center of each plot evidently had failed to keep the soil condition fit for healthy tree growth.

Improved aeration was provided for in one of the plots by laying six lines of 3-inch tile drain about 4 feet deep and 6 feet apart. The excavation for the tile lines was about 1 foot wide for the top 2 feet and then gradually flared out to nearly 4 feet wide at the base, thus forming an inverted trough. A main connecting tile line opened in a shallow well 100 feet away from the plots. After the tile was laid in place in the center of the ditch, the excavation was filled with coarse gravel to within 2 feet of the surface. The remaining 2 feet of the excavation was filled with the original soil. The ground in both plots was prepared for planting by plowing under and discing the remains of heavy manure mulch that had accumulated for 10 years.

In the fall of 1938, one lot of 2 year McIntosh apple trees (Series A) was planted 12 feet apart on the square with an additional tree in the center of each square. The following fall, another lot of similar trees (Series B) was planted as fillers among the 1938 lot, so that all trees were 6 feet apart each way. The two plots thus planted consisted of five rows each with two or three trees of the 1938 planting and two or three trees of the 1939 planting. The tile lines ran between the tree rows so that all trees were planted on ground undisturbed except for plowing. Both plots were heavily mulched with a 4-inch layer of wood shavings to conserve the rainfall and soil moisture. No weeds were allowed to become established during the two growing seasons.

Permanent gas sampling tubes similar to those described by Boynton and Reuther (3) were installed at four locations in each plot. At each

location the air was withdrawn at 1 or 1½ foot and at 3 foot levels below the surface. Samples of soil air were obtained about once a month during the dormant period and every 10 days to 2 weeks during the more active growing season. Data concerning girth increase, shoot growth, and the number and area of the leaves of every tree were obtained at the end of each season.

Discussion of the Results

Soil Air:—The data for oxygen and carbon dioxide determinations are summarized in Table I. The values given are the averages of the

TABLE I—Oxygen and Carbon Dioxide in Soil Atmosphere on Naturally and Artificially Drained Plots‡ (Cornell Orchard A)[1]

Date	Rain-fall† (Inches)	1–1½ Foot Level				3-Foot Level			
		Per Cent O_2		Per Cent CO_2		Per Cent O_2		Per Cent CO_2	
		A	B	A	B	A	B	A	B
1938									
Dec. 6...	3.37	17.0	20.1	1.2	0.6	*	17.6	*	1.3
1939									
Jan. 10..	1.63	16.6	20.1	1.4	0.6	10.7	17.0	1.9	0.8
Mar. 6...	6.13	18.0	20.1	1.0	0.6	*	18.0	*	0.7
Apr. 11..	3.71	10.9	20.1	1.4	0.7	*	17.1	*	0.7
May 10..	1.40	11.7	17.7	4.4	2.5	16.0	16.1	3.9	2.2
May 25..	0.80	10.4	14.7	5.4	4.3	3.9	13.4	4.1	3.0
June 9...	1.39	5.3	14.3	5.8	5.6	2.4	11.5	6.1	4.7
June 20..	1.67	4.5	8.6	7.8	10.3	1.9	6.6	5.6	6.3
July 14..	0.73	12.6	16.0	6.0	5.7	11.7	14.7	5.7	5.0
Aug. 23..	4.16	12.6	15.5	6.4	5.7	8.9	14.9	6.8	5.3
Sept. 18..	0.68	13.7	17.8	6.2	3.5	11.4	17.8	6.8	3.6
Oct. 18..	2.75	13.5	16.1	5.0	3.5	10.0	10.0	6.6	6.6
Nov. 29..	2.49	15.7	18.1	3.7	2.4	8.0	17.6	4.9	1.9
1940									
Feb. 12..	4.37	18.1	20.1	1.3	0.6	12.8	19.9	4.6	0.9
April 2...	5.83	3.3	20.0	1.1	0.7	10.4	19.0	1.7	0.9
April 17..	1.46	19.2	20.0	0.6	0.7	2.6	18.5	7.2	0.9
April 29..	1.86	17.6	20.1	1.1	0.7	4.5	16.8	7.5	1.3
May 13..	1.05	15.4	18.1	3.4	1.7	5.6	14.9	6.3	1.8
May 27..	2.68	14.3	12.8	6.3	3.3	1.4	11.9	8.2	3.0
June 12..	1.64	0.7	8.1	9.3	7.4	0.3	7.7	8.7	5.8
June 26..	2.04	4.7	15.6	8.8	4.3	2.6	14.0	15.9	4.1
July 9...	2.70	10.8	10.3	8.3	8.5	3.7	7.0	13.7	8.1
July 24..	0.57	7.9	12.4	11.3	8.6	0.8	8.2	13.6	8.9
Aug. 7...	2.14	8.9	15.3	11.9	4.2	0.3	10.8	15.5	6.7
Aug. 21..	0.37	9.2	17.2	10.6	4.3	3.2	15.0	12.4	5.7
Sept. 9...	0.98	15.0	18.8	5.9	1.9	8.5	15.4	10.5	3.1
Oct. 22..	3.30	10.9	18.4	6.1	1.8	5.3	15.7	9.6	2.5
1939 Average by Periods									
Jan. 10–May 10...		14.8	19.5	2.1	1.0	10.1	17.1	3.1	1.1
May 25–Aug. 23...		8.9	13.8	6.2	6.3	4.7	12.1	5.0	5.0
Sept. 18–Nov. 29..		14.3	17.6	4.8	3.0	9.7	17.1	6.1	3.1
1940									
Feb. 12–May 13...		16.7	19.6	1.9	0.9	7.5	17.7	5.5	1.1
May 27–Aug. 21...		7.3	13.0	9.3	5.7	1.2	10.6	12.0	4.2
Sept. 9–Dec. 8.....		12.1	18.8	5.7	1.6	6.5	15.8	9.3	2.3

A—Natural aeration.
B—Improved aeration.
*No air sample could be obtained.
†Rainfall since previous sampling.
‡Each figure represents average value of four permanent sampling locations.

[1]The authors wish to acknowledge the assistance of Walter Reuther, Louis Edgerton, and Cecil Compton, who from time to time have helped in obtaining samples of the soil air and making the determinations.

data from all the stations that could be sampled on the dates given. There was very little difficulty in sampling from all the installations on the plots with improved aeration, but on those with normal aeration the resistance encountered sometimes prevented the withdrawal of a sample of air especially during the early part of the seasons. In a few instances it was impossible to obtain samples from even a single location at the 3 foot level. Even though the stations were only about 12 feet apart, there was considerable variation among them in the composition of air withdrawn at a given date, but the average figures fairly represent the trend in all of them throughout the season.

That the provisions for aeration have been helpful in improving the oxygen supply of the soil is indicated by the fact that the values obtained at all sampling dates are consistently higher than under natural aeration at both the 1 and 3 foot levels. The carbon dioxide content, on the other hand, tends to be higher in the latter case. Variations from one sampling date to another are probably due to the daily fluctuations in the weather conditions which affect the pore space and biological activity in the soil. It is interesting to note that the oxygen content averaged lowest in each plot during the most active part of the growing season from about the middle of May to the latter part of August in each year. The carbon dioxide content was also highest at that time. During this period the soil would be relatively warm and there would be a high level of biological activity resulting in greater respiration.

It should be noted that the lowest oxygen content was not necessarily accompanied by the highest carbon dioxide percentage, although in general when the former is relatively high the latter is relatively low. In one location the carbon dioxide content of the soil reached a very high level of 33.6 per cent. There was no oxygen present with this high carbon dioxide. In another case, however, with the carbon dioxide at 19.3 per cent there was still 5 per cent of oxygen.

The data indicate a relationship between the composition of air and the amount of rainfall previous to the sampling dates. There was considerably less rainfall during the early part of the growing season of 1939 than there was in 1940. This is reflected in a lower oxygen content and a higher carbon dioxide content in the latter year, especially at the 3 foot levels. Plots with improved aeration showed nearly as much oxygen at this level in 1940 as in 1939, but under poor aeration conditions there was considerably less oxygen at this level in the latter year. It is interesting to note that the well aerated plot had about as much or even more carbon dioxide in the surface 18 inches as at the 3 foot level during both seasons. The naturally aerated plots, on the other hand, usually showed somewhat more carbon dioxide at the lower levels than at the high levels, and this difference was more pronounced during the wet season. The low values for oxygen in the 12 to 18 inch levels are due, in part at least, to heavy rainfall or low evaporation from the soil for a few days preceding the withdrawing of the sample. There was practically no runoff from the plots and the mulch greatly reduced evaporation from the surface. Where the trees made little leaf surface, only a small amount of soil moisture was with-

TABLE II—Soil Aeration and Average Growth Responses of Young McIntosh Apple Trees*

Series	Growing Season	Soil Aeration	
		Natural	Improved
	Total Leaf Area (Sq In)		
A1	1st 1939	244	596
A2	2nd 1940	807	3361
B1‡	1st 1940	161	554
	Total Shoot Growth (Cm)		
A2	2nd 1940	288	1343
B1	1st 1940	19	78
	Gain in Trunk Cross Section (Cm^2)†		
A2	1939–40	1.09	3.69
B1	1940	0.47	0.80

*Thirteen trees under each condition each season.
†Original cross sectional area 1.60 cm^2.
‡Seven trees of this series failed to live throughout the season although they formed leaves in early summer.

drawn by transpiration. The open pore space was thus kept at a minimum as previously indicated under such conditions. It was more difficult to obtain air samples, and impossible to do so in several locations on the poorly aerated plots.

Tree Response:—The response of the trees is indicated by the data in Table II. It is obvious from these figures that the improved aeration resulted in much better growth than was obtained with natural aeration.

As indicated by the leaf area the trees in Series A1 which were established during the relatively dry season of 1939 made about 50 per cent better growth on the naturally aerated plots than the trees in Series B1 which were established during the relatively wet season of 1940. On the plots with improved aeration, however, there is relatively little difference between the average of the first year's growth of these two series in the two years. While tree growth on the plot with improved aeration was much better than on the other plot in both years, the differences were especially marked during the relatively wet season of 1940. All the trees of Series A that were making their first year's growth on the plots in 1939 lived throughout the year under both treatments. All the trees of Series B that were making the first year's growth on the plots in 1940 pushed their buds and unfolded leaves. But before the end of the season seven of the trees on the poorly aerated plot died. The leaves on such trees began to wilt and dry up during the period of high temperature and high evaporation at the end of July. In Table II the trees are credited with the amount of leaf surface they had before they died.

It is obvious from this experiment that the soil which previously supported only weak tree growth in spite of ordinary tile drain and mulching with strawy manure, can be made to support very satisfactory growth provided the aeration in the soil can be improved. Another experiment indicates that the gradual decline which often begins on a few limbs of one side of mature McIntosh trees grown

under unfavorable soil conditions may be checked rather quickly by providing aeration close to the trunk of such trees. Within a few weeks after a tile covered with a foot or more of gravel was laid in early summer to within a few feet of the trunk, the leaves became normally green and the weak side of the tree could no longer be distinguished by poor leaf color from the healthy side. A nearby check showing similar symptoms continued with the abnormal leaf color throughout the season.

It is, of course, not always economic to take the necessary steps to improve the soil aeration that interferes with tree growth. These experiments emphasize the importance of determining soil aeration conditions before the orchard is planted. No other cultural means will overcome the fundamental handicaps of poor aeration which incidentally may involve more than good drainage.

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Relation Between Soil Organic Matter and Available Moisture Under Different Orchard Cultural Systems

By LEON HAVIS, *Ohio Agricultural Experiment Station, Wooster, Ohio*

THE relationship of soil organic matter content to the available moisture of the soil is a problem in which there has been considerable controversy in recent years. It is often stated, and it is usually true, that organic matter raises the moisture-holding capacity of the soil. The problem of the relative amount of this increase in soil moisture which is available to the plant is, however, a different and more vital one. The available moisture (or potential available moisture) content is at present considered as the difference between the field capacity (or moisture equivalent) and the wilting percentage.

The purpose of this study was to determine the relationship between the soil organic matter content and the potential available moisture capacity of an orchard soil under sod, mulch, and cultivation treatments. The investigations were made to determine the value of an increase in organic matter by such standard cultural practices as mulch and sod to the available moisture of the soil.

As horticulturists, we are principally concerned with organic matter in the form in which it is present in the soil complex following long periods under a given cultural system.

Feustel and Byers (7) determined the available moisture capacity of various mixtures of peat and soil. They concluded that "The use of peat as a soil amendment for the sole purpose of conserving a supply of available moisture is not recommended, except, possibly, in the case of a decomposed type of peat with sand or a very sandy soil". In another reference (2) is the implication that the addition of large amounts of organic matter to the soil had little or no effect on the available moisture content. Boynton and Batjer (4), after determining the moisture equivalent and total nitrogen of an orchard soil, concluded that there had been an increase in available moisture and organic matter under the mulched area as compared with that not mulched. Bouyoucos (3) used various laboratory mixtures of mineral soils and organic materials to determine the effect of organic matter on the available moisture of soils. He used his own recently introduced techniques of determining the wilting point by the dilatometer method and the moisture equivalent by the suction method. The results obtained by these methods indicate considerable direct relationship between percentage of organic matter added and available water increase. More recently, Stone and Garrison (11), using the Bouyoucos methods of determining available moisture, obtained similar results. Pinckney and Alway (9) have shown that there is more individual variation in results obtained by the suction method (used by Bouyoucos) than in those secured for moisture equivalent by the centrifuge method. Furthermore, the results are usually higher by the suction method, considerably so for sandy soils.

The Orchard and Methods Used

The apple orchard used in these studies is known as Orchard C of the Ohio Experiment Station. It was planted in 1915. The soil is classified as Wooster silt loam. Half the trees in this orchard have been in continuous cultivation with two cover crops each year. During most years soybeans and rye were used, but Sudan grass and oats have been substituted for the soybeans in a few years. The other half of the orchard was planted in bluegrass sod, and the mulch system was begun at once. Three cultural systems may be considered, therefore, cultivation, sod, and mulch. Other orchard practices have been the same in all three treatments. The tree roots are well distributed to a depth of about 6 feet in both treatments.

The soil samples were taken at two general locations in the orchard during July and August, 1940. At each location 14 borings were made in each of the three treatments to a depth of 5 inches. Previous studies (8) had shown that the organic matter was not significantly different in these treatments below that depth. All borings were within 20 feet of each other in the sod, mulch, and cultivation treatments. The cultivation and mulch samples were taken under adjoining trees; the sod samples were secured between mulched trees. The samples from each treatment were composited, air-dried, and run through a 2 millimeter screen.

The organic matter determinations were made on samples ground in a ball mill and passed through a 100-mesh sieve. The chromic acid (1, 10) method of organic matter determination was used.

The wilting percentage was found by use of dwarf sunflowers, following, in general, the method originally suggested by Briggs and Shantz (6). The moisture equivalent was determined by use of the centrifuge (5). Since it has been shown the moisture equivalent is not a good measure of the field capacity of all soils (12), direct determinations of field capacity by means of cylinders in the actual orchard soil were made. These determinations were compared with the moisture equivalent of soil from the same cylinders. It was found that the

TABLE I—Relation Between Soil Organic Matter and Available Moisture, 0 to 5 Inches Depth. (Available Moisture Calculated as Difference Between Moisture Equivalent and Wilting Percentage, Orchard C, 1940)

Treatment And Location		Organic Matter (Per Cent)	Mean Moisture Equivalent (Per Cent)	Mean Wilting Percentage	Available Moisture (Per Cent)
			Location A		
Cultivation	2–2	2.10	22.09 ± .05	5.72 ± .11†	16.37 ± .12
Sod	3–2	3.15	24.76 ± .15*	6.80 ± .11*	17.96 ± .18*
Mulch	3–2	3.05	24.47 ± .06*	6.75 ± .12*	17.72 ± .13*
			Location B		
Cultivation	2–5	2.55	23.04 ± .10	5.83 ± .14†	17.21 ± .17
Sod	3–5	3.14	25.33 ± .10	6.63 ± .15*	18.70 ± .18
Mulch	3–5	3.52	26.90 ± .32	7.18 ± .16	19.72 ± .35

*Combinations not significantly different from each other.
†Combinations not significantly different from each other.

moisture equivalent is a very good measure of the field capacity of this soil.

At least 10 determinations were run for each mean moisture equivalent and wilting percentage presented in Table I. The standard error of each mean is also presented. The value of the difference between each moisture equivalent mean and all other moisture equivalent means was found, and their standard errors were calculated. The same was done for wilting percentage means. Differences were counted as significant if the odds were greater than 19 to 1. The available moisture was obtained by subtracting the wilting percentages from the moisture equivalents and determining the standard error of each difference. The difference between each available moisture percentage and all other available moisture percentages was then calculated with the standard error of each difference. Here too, the significance of the differences was determined on the basis of 19 to 1 odds.

The organic matter determinations, as well as the moisture equivalents and wilting percentages, were calculated on the basis of the dry weight of the soil.

Results

The organic matter determinations show that as already noted (8), the amount of organic matter was considerably less under the cultivation than under the mulch and sod treatments, even though cover crops had been used. The mulch and sod were about equal in organic matter in location A, but in location B (Table I) the organic matter was significantly higher under the mulch than under the adjoining sod. Such soil variations are not unusual in this type of study. The difference in organic matter content between the cultivation and sod at location A was 1.05 per cent, which amounts to about 7.5 tons per acre of air-dry organic matter.

The moisture equivalents increased with the organic matter percentages at each location. If both locations are considered together, there was also a direct relationship in all cases except one (Table I). The small difference in organic matter content between the sod and mulch treatments in location A resulted in no significant difference in their moisture equivalents.

The mean wilting percentages varied directly with the organic matter content in every case, but several combinations showed lack of significance of differences (Table I). As may be noted, the standard errors were relatively greater here than they were for the moisture equivalent means.

The available moisture percentage was obtained by finding the difference between the wilting percentage and the moisture equivalent. When each available moisture percentage is paired with each other available moisture percentage, their differences were found to be significant in all cases except one (Table I). The small difference in organic matter between the sod and mulch at location A (0.10 per cent) resulted in no significant difference in available moisture. As already noted, the differences in moisture equivalents and wilting percentages between this pair also lacked significance.

No definite proportionate relationship between increases in organic matter content and available moisture could be established from this study. Nevertheless, it may be noted that the sod contained 1.05 per cent, or about 7.5 tons, more organic matter than did the cultivation at location A, and this amount was evidently responsible for a difference in available moisture of 1.59 per cent, or about 3,000 gallons per acre. The mulch and cultivation at location A (Table I) differed by 0.95 per cent, or 6.8 tons per acre, in organic matter, and by 1.35 per cent, or about 2,400 gallons, of available water per acre. These approximations would not hold true for many other soils and would probably not be exactly the same during every year in the orchard used here.

The increase in available moisture would, of course, be potentially available in the soil every time it reached its field capacity during the season. Obviously, as in the bluegrass sod, all the available water would not be used by the trees, and lack of thorough tree root distribution would make some of it unavailable even if the amount used by the sod were considered.

It may be concluded that under the conditions of these studies, the differences in organic matter due to different orchard cultural practices have resulted in significant differences in available moisture. The differences are not great, and the value of the increase in available moisture due to organic matter is dependent upon several other factors, such as tree root distribution, type and depth of rooting of cover crops and sod, relative amount of transpiration and evaporation, and number of times the soil is saturated during the year. Once the soil reaches field capacity under the mulched area, a relatively large amount of the moisture in the topsoil is available to the tree roots. Here, however, is the factor of lack of absorption by the soil of all the water which falls on the mulch. Other effects of the different orchard management systems, as well as other effects of differences in soil organic matter, are not considered here.

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The Potassium Nutrition of Fruit Trees III. A Survey of the K Content of Peach Leaves from One Hundred and Thirty Orchards in California[1]

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CALIFORNIA has 98,077 acres (1) planted to peach trees. With so large an acreage and with many climatic and soil differences it has not been physically possible to adequately test, by field trials, the potassium needs of peach orchards within the state. It was suggested that progress might be made through use of leaf analyses. To date, fertilizer trials with peach trees in California have not shown any benefits from potassium. However, some response to K has been secured in limited areas with prune trees. Here the untreated trees have invariably had a low leaf K. Though low K values in the leaf may not be infallible criteria of a potassium deficiency, they are probably, in the absence of leaf symptoms, our best single guide as to where field trials with peach trees might be established most advantageously. This was the objective of the survey described herein. A study of factors which influence the leaf K content of the peach and affect the interpretation of the survey data is also included.

Methods of Sampling and Analysis

Varieties and Location of Plots:—The sampling was limited to four important varieties, two clingstones, the Phillips and Paloro, and two freestones, the Elberta and Lovell. The plots were all in the Sacramento and San Joaquin Valleys and the number of orchards sampled in each county was roughly in proportion to its peach acreage. The county agents selected and mapped the plots consisting of 10 trees each and furnished information as to their age, previous productivity, and so on.

Method of Leaf Sampling:—All samples were collected in the field by the authors. Ten basal leaves from the current season's growth from each of the 10 trees constituted the samples. In a few instances when spray residue was evident, the leaves were washed. Otherwise the sample was placed in a manila envelope and sealed. It was not feasible in the case of the more distant samples from the San Joaquin Valley to get these into the dehydrator until 3 days after sampling. Tests to simulate this transit delay indicated an increase in the K percentage of less than 0.2 per cent over corresponding samples placed immediately in the dehydrator. Differences between low and high K orchards were generally expected to exceed this error.

Tree Variability:—Duplicate samples of 100 basal leaves from the same tree generally do not differ by more than 0.2 per cent K. How-

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TABLE I—Variations in the Leaf K Content of Individual Trees (Phillips Cling Orchard, Row 11, University Farm, Davis, Age 18 Years)

Tree No.	Per Cent K in Dry Leaf Matter					Yield 1940 (Lbs)
	Jun 26	Jul 25	Aug 12	Aug 26	Sep 12	
11-2	2.07	1.78	1.75	1.60	1.39	311
11-3	2.20	2.10	1.81	1.79	1.40	332
11-4	2.07	1.70	1.74	1.75	1.39	385
11-5	2.18	1.93	1.77	1.75	1.56	355
11-6	2.03	1.74	1.62	1.58	1.45	393
11-7	2.51	2.19	2.09	2.09	2.17	187
11-8	2.11	1.79	1.81	1.83	1.55	250
11-9	2.73	2.83	2.54	2.57	2.22	210
11-10	2.33	1.93	1.92	1.84	1.74	—
Average Row 11	2.25	1.99	1.90	1.86	1.65	—
P E M	±.052	±.079	±.061	±.067	±.072	—
Average Row 10	2.40	2.03	1.86	1.88	1.56	—
P E M	±.044	±.056	±.054	±.060	±.063	—

ever, tree variations greatly exceed this as shown in Table I, which presents the data from nine trees in row 11 in the Phillips Cling orchard in the University Farm at Davis. These 18-year-old trees are of uniform size and are growing on a deep uniform soil.

The data immediately suggest that consideration must be given to sampling an adequate number of trees in any foliar survey of potassium. Included in Table I are the averages and their probable errors for row 11 and also for a similar number of trees in the adjacent row 10. The agreement between the averaged data and their probable errors suggest that 10 trees may be an adequate sampling for a foliar survey. It is also apparent that the variability in row 10 is of the same order of magnitude. Since the accuracy of sampling and analyses is approximately ±0.1 per cent K there appears to be no reason for extending the sampling to a number of trees greater than 10. A similar study of individual tree data from a 6-year-old Elberta peach orchard at Paradise showed a tree variability comparable to that reported in Table I and suggests that such variability between trees may be of common occurrence.

Table I further shows that the individual trees maintain their high or low K content throughout the 1940 season. Unpublished data from individual prune trees show, however, that the superior status of a high K tree is not always maintained in following seasons. Thus a tree which distinctly exhibits a superior K status in one season may, during the following year, be at a constantly lower K level. The averages of 10 trees, however, remain about the same from year to year. Such

TABLE II—Comparison of K Contents of New and Old Leaves August 1939

	Per Cent K in Dry Leaf Matter			
	Peach No. 1	Peach No. 2	Prune	Almond
New leaves—terminal on 2nd growth cycle	1.45	1.69	1.94	1.67
Old leaves—basal on 1st growth cycle	1.87	2.54	2.54	2.24

transient K levels indicate the importance of factors other than the soil in determining the leaf K content of individual trees and stress the need of sampling an adequate number of trees.

All the samples were from basal leaves on current season's growth. This method was adopted in our earlier work to eliminate errors which might be due to sampling leaves of different ages. However, later analyses (Table II) indicate that such differences may not be as large as expected, thus permitting a greater latitude in sampling and a comparison of analyses from different sampling techniques.

The data in Table II represent extremes in leaf age. The new leaves were from the terminals on the second cycle of growth and had just unfolded on the day of sampling while the old leaves were the basal ones in the first cycle which represent our general sampling method. The basal leaves were 4 months older and this age difference would therefore greatly exceed any variations which might occur in foliar sampling. While the differences between new and old leaves are appreciable, they do suggest a much smaller difference between basal and middle leaves on the current shoot growth of the first cycle and a possible direct comparison of our data with that of other investigators who have chosen to sample leaves from the middle portion of the shoot.

The analyses are of further interest in that they show a lower per cent K in the immature leaves. In contrast, phosphorus was found to be higher in the younger leaves.

Leaf petioles have been used in some of the "quick tests". Our criticism of the quick test, as reported in our earlier work (2) is its limited accuracy. A comparison *by standard chemical methods* of the K in petiole and leaf blade showed a high correlation in both peach and prune trees and failed to suggest any diagnostic advantage in the petiole data, or in the ratio between petiolar and blade K contents.

Time of Sampling:—Some earlier work (Table III) with 10-year-old J. H. Hale peaches and also some data on Elbertas indicated that the potassium content of peach leaves remained fairly constant during the midsummer months of June and July and sampling was therefore confined to this interim. There is a decline in the per cent K later in the year but its time of occurrence varies with the season. Its early

TABLE III—SEASONAL TREND OF POTASSIUM IN PEACH LEAVES

Description	Year	Per Cent K in Dry Leaf Matter					
		May	Jun	Jul	Aug	Sep	Oct
Variety J. H. Hale, planted 1921, soil Aiken c.l, McCarthy orchard; Paradise, California	1931	3.17	—	2.61	1.88	—	—
	1932	2.61	2.80	2.59	2.38	2.35	—
	1933	2.65	2.70	2.79	2.12	1.75	—
Variety Elberta, planted 1934, soil Aiken c. l, Ream orchard; Paradise, California.......	1934	—	—	—	2.28	2.21	—
	1935	—	2.88	2.76	2.39	2.31	1.76
	1936	—	2.78	—	2.90	2.94	2.49
	1937	—	2.84	2.64	—	—	—
	1938	—	—	2.93	—	—	—
	1939	—	2.56	2.49	1.63	—	—
Variety Elberta, Ream orchard, planted 1938	1939	—	2.37	2.32	1.74	—	—
Variety Elberta, Ream orchard, planted 1937	1939	—	2.77	2.78	1.64	—	—

occurrence in 1939 may be noted in August (Table III) and is evident not only the trees planted in 1934 but also in the younger 1937 and 1938 planting. The inference is that certain environmental factors in the 1939 season were able to effect an unusually early K withdrawal and it would therefore not seem advisable to make comparisons in any two seasons between K values obtained later than July.

It was concluded from these data to limit the samplings in the survey to one in June and another in July with the expectancy that one would serve as a check for the other and also to give us a greater opportunity to observe any possible differences in the growth status of the trees which might later be correlated with the K analyses.

It is also of interest to note, since the survey included trees of varying age, that the K contents of the leaf in Table III do not appear to be influenced by the age of these trees.

The Effect of Crop on Leaf K:—It has been our experience with prune trees that heavy bearing markedly affects the K content of the leaf (2). It may be noted in Table I that the two Phillips peach trees with the highest K content had the lightest crops. Since peach trees are regularly thinned and prune trees are not, their fluctuations in yield and their tendency to alternate are not as great. Fluctuations in K content of peach leaves due to variations in size of crop may not therefore be of as great a magnitude. The data in Table IV contrast the average

TABLE IV—The Effect of Crop on the Leaf K Content of the Muir Peach

	Per Cent K in Leaf Dry Matter						
	May 1	May 16	Jun 14	Jul 5	Jul 25	Aug 2	Aug 26
Not bearing (disbudded)....	1.18	1.45	1.80	1.82	1.80	1.81	1.66
Bearing..................	1.12	——	1.75	1.63	1.32	1.15	0.98

K contents of leaves from two peach trees bearing normally with two adjacent uncropped trees which had all their flower buds removed just prior to full bloom. There was a marked response in growth and leaf size as early as May 1 in the trees having no crop but significant differences in the K content of the leaf do not appear until the latter part of July. It might be concluded from these data that while differences in the K content of the leaf due to differences in crop have been produced by this extreme treatment, one could not likely ascribe any large differences found in the survey to differences in size of crop. Not only were the survey samples taken prior to July 25, when differences in Table IV became apparent, but the orchards in general were with few exceptions carrying normal fruit loads. Had the differences in Table IV been of a greater magnitude and of an earlier occurrence, they might have seriously affected the interpretation of the data obtained in the survey. Sampling of peach leaves late in the season should be avoided therefore not only because of differences between seasons but also because the differences due to variations in size of crop become more evident at the later dates.

Effect of Soil Moisture on Leaf K:—All the orchards in the survey

received from three to five irrigations during the summer. Variations in soil moisture could not be avoided in the survey. It was desirable to know how soil moisture might affect the K content. Leaf samples taken from the same trees before and after irrigation in two of the orchards did not differ significantly in their K contents. No soil moisture samples were taken but from previous knowledge of the moisture relationships in these soils and the frequency of irrigation, the soils had not reached the wilting point when the water was applied. This might be considered typical of general grower practice and it is therefore assumed that soil moisture variations as they existed in the orchards in the survey did not cause large differences in the leaf analyses.

In another comparison, leaves from the irrigated and non-irrigated Phillips Cling plots in the experimental irrigation orchard at the University Farm show that lower K values do occur in the plot which has been allowed to fall below the wilting point annually since 1931. The experiment is described in detail by Hendrickson and Veihmeyer (4) and the data in Table V are from treatments D (dry) and A (wet). The trees in the dry plot are strikingly inferior and the foliage, when sampled, was likewise. Extreme reductions in soil moisture which might be considered tantamount to cultural neglect may after a period of years produce lower K values in the peach leaf. None of the orchards in the survey appeared to have suffered from a moisture deficit as great as that found in row 2.

TABLE V—THE EFFECT OF SEVERE DROUGHT ON K ANALYSES OF LEAF (PHILLIPS CLING IRRIGATION ORCHARD, UNIVERSITY FARM, DAVIS, 1940)

Row	Treatment	Per Cent K in Dry Leaf Matter				
		Jun 26	Jul 25	Aug 12	Aug 26	Sep 12
2	D (dry)	1.76	1.45	1.20	1.14	1.03
11	A (wet)	2.25	1.99	1.90	1.86	1.65

Effect of Potassium in the Soil on Potassium in the Leaf:—Soil samples were taken in all the plots represented in this survey but have not been analyzed. However, our earlier work with prune trees (3) indicated little or no relationship between the replaceable K and the leaf analyses when several soil types were studied. The Neubauer method showed greater agreement. Many recent analyses of fertile soils, particularly those classified as of young granitic origin, have shown low replaceable K but high Neubauer values.

However, the problem of evaluating such factors as soil texture and

TABLE VI—THE EFFECT OF UNFAVORABLE ROOT ENVIRONMENT ON K CONTENT OF PRUNE LEAVES

Orchard	Soil K Ppm. (Neubauer)					Leaf K Per Cent	Soil and Tree Condition
	1-Foot	2-Foot	3-Foot	4-Foot	Average		
Mills	345	211	197	102	242	0.61	Plastic clay—scorch
McQuilken	285	175	165	154	195	0.68	Poor drainage—scorch
Canfield 11–16	276	200	157	146	195	2.27	Loam well drained—healthy

TABLE VII—PEACH LEAF K (SURVEY 1940)

Per Cent K in Dry Leaf Matter			Orchard	Age	Tree Size	Foliage	Yields (Tons/Acre)	Soil Type*	County
Average	June	July							
						Elberta Variety			
3.43	3.72	3.14	Di Giorgio Co.	4	Small	Good	—	Arvin loamy f. s.	Kern
3.35	3.80	2.91	C. H. Hansen	17	Small	Poor	6	Arvin loamy f. s.	Kern
3.13	3.38	2.89	Penryn Fruit Co.	19	Small	Good	8	Holland s. l. (shallow)	Placer
2.83	2.81	2.85	Penryn Fruit Co.	19	Small	Good	—	Holland s. l. (very shallow)	Placer
2.82	2.98	2.66	Patterson Ranch Co.	20	Average	Very excellent	13	Yolo c. l.	Stanislaus
2.81	3.18	2.45	J. Anderson	18	Average	Fair	18	Fresno s. l.	San Joaquin
2.47	2.60	2.35	W. P. Boone	35	Average	Good	9	Greenfield s. l.	Tulare
2.44	2.74	2.14	N. Davis	14	Small	Good	14	Hanford s. l.	San Joaquin
2.40	2.76	2.05	P. B. Fitzpatrick	22	Average	Fair	9	Fresno s. l. (brown)	San Joaquin
2.33	2.22	2.45	C. Preuss	35	Average	Excellent	14	Madera s. l.	Fresno
2.32	2.71	1.93	E. M. Vaughn	20	Small	Poor	5	Vina l. (shallow)	Tehama
2.29	2.58	2.01	L. C. Bline	7	Small	Poor	5	Tehama silt l.	Tehama
2.18	2.39	1.98	J. Palhorn	5	Large	Good	12	Gridley l.	Butte
2.17	2.54	1.80	G. Merrill	12	Average	Good	20	Columbia f. s. l.	Tehama
2.17	2.33	2.01	University Farm	18	Average	Fair	8	Yolo c. l.	Yolo
2.08	2.07	2.09	F. Beard	5	Large	Very excellent	—	Fresno f. s. l.	Stanislaus
2.06	2.42	1.71	E. S. Lindauer	18	Large	Excellent	17	Columbia f. s. l.	Tehama
2.02	2.36	1.67	W. T. Delano	20	Small	Fair	10	Madera s. l.	Fresno
2.02	2.35	1.69	C. E. Zirkle	4	Small	Good	—	Hanford s. l.	San Joaquin
2.00	2.16	1.84	L. R. DeVincenzi	11	Average	Good	8	Wyman c. l.	San Joaquin
2.00	2.24	1.77	J. G. Sutton	25	Average	Excellent	15	Capay silty c. l.	Solano
1.96	2.23	1.70	T. A. Jenkinson	14	Large	Chlorotic	6	Hanford f. s. l.	Kings
1.94	2.32	1.56	C. Roberts	33	Average	Chlorotic	2	Yolo silty c. l.	Solano
1.78	2.16	1.40	J. H. Murray	17	Average	Sli'tly chlorotic	6	Yolo silty c. l.	Solano
1.78	1.89	1.67	P. Dodini	10	Average	Excellent	15	Yolo silty c. l.	Solano
1.67	2.09	1.25	G. Montrose	6	Small	Fair	4	Madera s. l.	Fresno
1.66	1.76	1.56	Buck Ranch	14	Average	Good	14	Gridley l.	Sutter
1.64	1.81	1.47	J. Perry	15	Large	Very excellent	11	Chino f. s. l.	Tulare
1.58	1.84	1.33	S. Serabian	13	Average	Very excellent	20	Fresno s. l.	Fresno
1.54	1.69	1.39	M. C. Jenkins	20	Large	Very excellent	18	Madera s.	Merced
1.37	1.71	1.03	C. A. Merrill	16	Average	Good	10	Traver l.	Kern
1.20	1.25	1.15	R. N. Finchen	22	Average	Excellent	15	Fresno s. l.	Fresno
1.14	1.29	0.99	H. F. Sill	29	Small	Poor	7	Elder silt l.	Tehama
1.12	1.32	0.92	R. Swanson	7	Average	Good	8	Hanford f. s. l.	Kings
1.10	1.28	0.93	F. Arthur	16	Large	Poor	11	Foster s. l.	Kings
1.06	1.30	0.82	G. H. Dresser	8	Small	Good	9	Fresno f. s. l.	Stanislaus
1.06	1.12	1.00	K. Lucey	7	Small	Good	7	Zamora c. l.	Solano
0.92	0.99	0.85	M. Kozuki	30	Average	Good	7	Oakley-Fresno s.	Fresno
0.83	1.01	0.65	E. B. Wood	32	Average	Good	12	Madera s.	Merced
0.73	0.84	0.63	F. Vierra	13	Average	Good	13	Hanford f. s. l.	Kings
0.70	0.86	0.54	C. Peterson	17	Small	Good	3	Maywood l. gravelly	Tehama
0.64	0.83	0.45	R. Blowers	19	Average	Good	—	Hanford f. s. l.	Kings

TABLE VII—*Continued*

Lovell Variety

3.28	3.93	2.64	C. K. Nakamura	10	Average	Excellent	10	Fresno s. l.	Fresno
2.53	2.67	2.39	D. M. Terry	18	Very large	Excellent	16	Chino f. s. l.	Tulare
2.32	2.50	2.14	W. V. Smith	19	Large	———	16	San Joaquin c. l.	Tulare
2.32	2.45	2.19	A. H. Wheeler	16	Average	Good	13	Gridley l.	Butte
2.32	2.41	2.22	Patterson Ranch	28	Average	Good	17	Yolo c. l.	Stanislaus
2.28	2.49	2.07	A. Metzler	13	Average	Good	11	Wyman silt l.	San Joaquin
2.22	2.37	2.06	G. H. Dresser	10	Average	Good	13	Fresno f. s. l.	Stanislaus
2.22	2.33	2.11	J. Ames	18	Average	Good	12	Gridley l.	Sutter
2.20	2.25	2.16	El Solyo Ranch	14	Average	Excellent	12	Yolo c. l.	Stanislaus
2.18	2.48	1.88	B. Oiz	4	Large	Excellent	—	Fresno s. l. (brown)	San Joaquin
2.18	2.36	2.00	C. Westenberg	5	Large	Excellent	4	Hesperia s. l.	Kern
2.12	2.09	2,15	W. S. Batterman	18	Large	Excellent	28	Madera s.	Merced
2.08	1.75	2.31	N. Davis	14	Small	Good	14	Hanford s. l.	San Joaquin
2.01	2.24	1.78	L. Strand	12	Average	Good	15	Fresno s. l. (brown)	San Joaquin
1.94	2.34	1.55	F. H. Weeks	18	Average	Fair	12	Columbia f. s. l.	Tehama
1.93	1.91	1.95	B. F. Butcher	11	Large	Good	20	———	Fresno
1.92	2.13	1.72	J. Palhorn	17	Average	Fair	13	Gridley l.	Butte
1.89	1.94	1.85	J. G. Sutton	25	Average	Excellent	15	Capay silty c. l.	Solano
1.87	1.95	1.79	University Farm	18	Average	Good	10	Yolo c. l.	Yolo
1.86	2.11	1.61	M. C. Jenkins	20	Average	Excellent	18	Madera s.	Merced
1.85	2.05	1.66	J. Palhorn	5	Average	Excellent	—	Gridley l.	Butte
1.76	1.81	1.71	F. Beard	16	Large	Good	15	Fresno f. s. l.	Stanislaus
1.44	2.17	0.70	A. M. Morton	7	Small	Chlorotic	—	Fresno s. l.	Fresno
1.41	1.46	1.36	C. Chase	9	Average	Good	13	Wyman c. l.	San Joaquin
1.07	1.38	0.77	R. Swanson	12	Average	Good	10	Hanford f. s. l.	Kings
0.93	1.04	0.83	Berry Estate	34	Average	Fair	—	Oakley-Fresno s.	Fresno

*The soil type data have been taken from the Soil Surveys, Bureau of Chemistry and Soils, U.S.D.A. The following abbreviations have been used: c—clay; f—fine; s—sand or sandy; l—loam.

TABLE VII—*Continued*

Per Cent K in Dry Leaf Matter			Orchard	Age	Tree Size	Foliage	Yields (Tons/Acre)	Soil Type*	County
Average	June	July							
					Paloro Variety				
3.25	3.67	2.84	A. Adrian	16	Large	Fair	13	Oakley-Fresno s.	San Joaquin
3.16	3.20	3.12	V. Hoffman	17	Very large	Excellent	18	Hanford s. l.	San Joaquin
3.12	2.96	3.28	E. F. Eckhart	15	Average	Excellent	4	Holland s. l.	Placer
3.08	3.36	2.81	Woodbridge Fruit	17	Average	Excellent	10	Hanford s. l.	S. Joaquin
3.04	3.38	2.71	G. Lindauer	18	Average	Fair	6	Vina f. s. l.	Tehama
2.85	3.12	2.58	R. W. Miller	17	Large	Good	12	Wyman silt l.	San Joaquin
2.75	3.02	2.49	H. R. Mehrton	13	Large	Excellent	18	Hanford s. l.	Tulare
2.70	2.52	2.89	S. Hamomoto	15	Small	Good	low	Holland s. l.	Placer
2.66	3.02	2.31	W. Vilen	16	Small	Poor	10	Fresno s. l. (brown)	San Joaquin
2.63	2.75	2.52	Patterson Ranch	18	Average	Fair	12	Yolo c. l.	Stanislaus
2.56	2.66	2.46	F. Bentley	16	Large	Excellent	13	Bear River silt l.	Sutter
2.31	2.64	1.98	F. Bremer	16	Large	Good	13	Gridley l.	Sutter
2.27	2.47	2.07	C. Wetmore	16	Large	Good	13	Feather silt l.	Yuba
2.25	2.41	2.09	L. Hudson	13	Large	Excellent	15	Bear River s. l.	Sutter
2.23	2.40	2.07	O. K. Fink	8	Large	Good	20	Hanford s. l.	Kings
2.20	2.35	2.04	H. G. Littlejohn	17	Average	Good	20	Gridley l.	Sutter
2.18	2.52	1.84	E. S. Weller	10	Fair	Poor	3	Hesperia s. l.	Kern
2.16	2.26	2.07	S. C. Davis	9	Average	Good	10	Fresno s. l.	Fresno
2.15	2.44	1.87	L. Martin	16	Average	Chlorotic	9	Foster f. s. l.	Tulare
2.12	2.28	1.97	A. K. Andross	3	Large	Good	—	Gridley c. l.	Sutter
2.05	2.15	1.96	C. K. Roddan	15	Large	Fair	12	Bear River s. l.	Yuba
1.96	2.17	1.76	Ord Ranch	14	Large	Excellent	12	Columbia silt l.	Butte
1.92	2.10	1.74	E. J. Weser	15	Average	Good	12	Gridley l.	Sutter
1.91	2.04	1.79	P. Erickson	13	Average	Good	11	Feather l.	Yuba
1.88	2.05	1.72	El Solyo Ranch	17	Large	Excellent	15	Yolo c. l.	Stanislaus
1.81	1.87	1.75	H. H. Welsh	13	Large	Excellent	13	Fresno s. l.	Fresno
1.68	2.03	1.33	M. Serimian	13	Very small	Fair	3	Fresno s. l.	Fresno
1.67	1.81	1.54	F. Fiorini	12	Small	Fair	6	Madera s.	Merced
1.66	1.81	1.52	E. B. Wood	20	Small	Good	7	Madera s. l.	Merced
1.58	1.74	1.43	C. H. Jones	16	Average	Fair	14	Fresno f. s. l.	Stanislaus
1.58	1.71	1.46	G. H. Dresser	12	Small	Fair	12	Fresno f. s. l.	Sranislaus
1.50	1.71	1.30	D. B. Harris	15	Large	Excellent	10	Fresno s. l.	Fresno
1.12	1.37	0.86	F. Arthur	13	Large	Good	7	Foster s. l.	Kings
1.12	1.17	1.07	M. Otteson	—	Small	Poor	6	Fresno s. l.	Fresno

TABLE VII—*Concluded*

Phillips Variety

3.02	2.96	3.08	Woodbridge Frt. Co.	17	Very large	Good	18	Columbia f. s. l.	San Joaquin
2.87	3.08	2.66	Woodbridge Frt. Co.	18	Average	Good	10	Hanford s. l.	San Joaquin
2.82	2.88	2.76	J. Punta	15	Average	Excellent	12	Wyman c. l.	San Joaquin
2.79	2.78	2.81	A. H. Hughes	18	Large	Excellent	12	Gridley l.	Butte
2.75	2.84	2.66	H. Rollins	18	Large	Good	16	Oakley and Fresno s.	San Joaquin
2.72	2.86	2.59	F. Bentley	16	Large	Excellent	15	Bear River silt l.	Sutter
2.69	2.76	2.63	C. Wetmore	16	Large	Excellent	16	Feather silt l.	Yuba
2.64	2.68	2.60	R. L. Tudsbury	42	———	Poor	8	Holland s. l.	Placer
2.60	2.58	2.62	H. A. Struble	36	Average	Fair	3	Holland s. l.	Placer
2.40	2.58	2.21	C. H. Jones	17	Large	Fair	15	Fresno f. s. l.	Stanislaus
2.28	2.29	2.28	J. C. Randell	18	Average	Good	7	Exeter l.	Tulare
2.19	2.33	2.05	University Farm	18	Large	Fair	5	Yolo c. l.	Yolo
2.19	2.30	2.09	L. Hudson	13	Large	Excellent	15	Bear River silt l.	Sutter
2.15	2.32	1.99	H. Fillmore	17	Average	Fair	14	Gridley l.	Butte
2.14	2.11	2.17	J. P. Schafer	16	Average	Poor	8	Fresno s. l. (brown)	San Joaquin
2.00	2.09	1.92	F. Bremer	16	Large	Good	15	Gridley l.	Sutter
1.87	1.95	1.79	H. H. Anderson	21	Large	Excellent	10	Hanford s. l.	Tulare
1.83	1.87	1.80	C. K. Roddan	15	Average	Fair	12	Bear River silt l.	Yuba
1.73	1.76	1.70	H. H. Welsh	12	Excellent	Good	12	Oakley-Fresno s.	Fresno
1.70	1.85	1.56	R. Klopping	15	Small	Poor	15	Yolo c. l.	Stanislaus
1.51	1.55	1.47	G. H. Dresser	10	Average	Fair	10	Fresno f. s. l.	Stanislaus
1.22	1.27	1.18	El Solyo Ranch	17	Large	Excellent	11	Yolo c. l.	Stanislaus
1.21	1.44	0.99	A. K. Andross	20	Small	Poor	10	Gridley l.	Sutter
1.14	1.06	1.22	D. Bache	18	Large	Excellent	15	Madera s.	Merced
1.09	1.10	1.08	W. B. Parker	13	Small	Fair	8	Wyman c. l.	San Joaquin
0.97	0.77	1.17	S. C. Davis	20	Large	Fair	10	Fresno s. l.	Fresno
0.57	0.63	0.52	J. G. Carlson	12	Average	Poor	3	Fresno s. l.	Fresno

*The soil type data have been taken from the Soil Surveys, Bureau of Chemistry and Soils, U.S.D.A. The following abbreviations have been used: c—clay; f—fine; s—sand or sandy; l—loam.

soil depth which together with soil structure and poor drainage affect the root environment of fruit trees cannot be studied by the Neubauer method. It is here that leaf analyses for K may be particularly helpful. The data in Table VI show a comparison of soil and leaf analyses from three prune orchard sites in which the Neubauer values indicated a sufficiency of potash but the leaf analyses in two of the orchards (Mills and McQuilken) are low and they have shown some response to K applications. The Mills plot was on a particularly heavy plastic clay and the McQuilken orchard suffered from excess water in early spring, draining down from the adjacent hillside. The site in the Canfield orchard is on a loamy well drained soil and though its K content is no higher than the other two soils, the leaf analysis excells the others by 200 per cent. Unfavorable root environments, many less obvious than these two, may produce some disagreement between Neubauer values and leaf analyses.

Discussion of Survey Data:—The leaf analyses together with certain orchard data are presented in Table VII. They have been grouped according to variety and in a descending order of their average June and July K contents. The Elberta values vary from 3.43 to 0.64 per cent K. There were no outstanding tree differences which could be correlated with the K content. Color, size, texture, shape and other leaf characters seemed to show no relationship to the K content. Leaves which were thin and pale were frequently as high in per cent K as dark green, heavy textured foliage. Referring to individual cases in Table VII, the leaves in the Peterson (Elberta) orchard, with a low K content (0.70 per cent) were larger and apparently healthier than leaves from the Hanson orchard with a distinctly high K content (3.35 per cent). The Serimian (Paloro) orchard which had made the poorest current growth of all orchards included in the survey had a moderately high K content (1.68 per cent), higher than the Harris orchard (1.50 per cent K) which had excellent tree growth and greater yields. The Weller (Paloro) orchard (2.18 per cent K) was distinctly inferior in foliage and growth to the very excellent Littlejohn (2.20 per cent K) orchard, yet the K contents were the same. Marked differences in foliage and tree size in this survey are not reflected in the K content of the leaf. Should response to K be obtained in any of these orchards then one would conclude that foliage and tree symptoms are not satisfactory guides for potash applications to California peach orchards.

In general, California peach trees are above the 1 per cent leaf K — a tentative limit of K sufficiency for fruit trees suggested by our data with prune trees (2), and that of Batjer and Magness (5) for apples, and Cullinan, Scott, and Waugh (6) and others for peaches.

The orchards which were below 1 per cent K in their foliage were re-examined in October for the possible appearance of late deficiency symptoms. Leaf samples were collected in some of the orchards at that time and the following data secured: Blower 0.27 per cent K, Peterson 0.47 per cent K, Vierra 0.75 per cent K, Swanson 0.76 per cent K. These analyses confirm the low values found earlier (Table VII). Observations at this time also failed to disclose any distinct scorch or leaf rolling. K plots in these low K orchards will be established later.

Distinct differences between the four varieties included in the survey are not evident in the data. The June averages and their probable errors are as follows: Elberta 2.09±.08; Lovell 2.18±.07; Paloro 2.39±.06; Phillips 2.09±.09. The July averages are: Elberta 1.66±.07; Lovell 1.83±.07; Paloro 2.01±.06; Phillips 1.98±.09.

Analyses of Elberta and Lovell leaves from adjacent rows in five orchards also failed to show differences which could be called characteristic of the variety. The June averages for the Paloro and Phillips suggest a possible higher K content for Paloro but five comparisons in which these two varieties were in adjacent rows did not show any consistent difference in favor of Paloro.

The lower K percentages in July (Table VII) were largely due to an increase in the dry weight of the leaf. Calculations based on the dry leaf weights showed that the actual amount of potassium in the leaf was approximately the same in the two months and the decrease in the percentage in July was therefore a "dilution effect" rather than a migration of K out of the leaf. The milligrams of K per leaf for June were as follows: Elberta 4.3; Lovell 3.6; Paloro 3.7; Phillips 3.3. In July the following values for the milligrams of K per leaf were obtained: Elberta 4.4; Lovell 3.8; Paloro 3.7; Phillips 3.7. It was noted in two orchards when there was little or no crop, that the leaf size in July excelled that of trees bearing normal loads and the weight of potassium per leaf in these showed greater increases than the above figures indicated.

Summary

Variations in the K content of the leaf were found between adjacent peach trees which appeared to be uniform in growth and on a uniform soil. Averages of ten trees showed satisfactory agreement.

Very young leaves were found to be lower in K than older leaves when examined in mid-summer.

Monthly analyses of peach leaves in several seasons showed the smallest change in the K percentage in June and July and suggested this interim as the most suitable time for a statewide survey study of the K content of leaves from peach orchards.

The K content of the leaf did not appear to be influenced by tree age.

The per cent K in the leaf was affected by the amount of fruit on the tree. The effect was evident in late July and thereafter.

Variations in soil moisture above the wilting point did not seem to produce any variations in the K content of peach leaves. Severe drought, produced by omitting irrigation in summer and reducing soil moisture below the wilting point for long periods each year, after a 9 year period did reduce the leaf K in peach trees.

The Neubauer method was found distinctly superior to base replacement in determining K availability for prune trees. An unfavorable root environment produced by heavy soils or poor drainage may produce a lack of agreement between soil analyses by the Neubauer method and leaf analyses of K.

No distinct varietal difference in leaf K in June and July could be determined between the following: Elberta, Lovell, Paloro and Phillips.

The average per cent K in the dry matter of the leaf in June and July in 130 California peach orchards was 2.0 per cent. The range was from .6 per cent to 3.4 per cent K.

No distinct leaf symptoms could be found in the trees showing a low leaf K.

Neither tree size nor current season's growth and foliage seemed to be related to the 1940 K leaf analyses.

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Effects of Organic Matter and Certain Growth Substances on the Development of Young Orange Trees in the Orchard[1]

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THE addition of organic materials, such as peat and manure, to the fill-back soil used in planting trees is a rather common procedure. Frequently such materials are also used as a surface mulch about trees after planting. The value of such practices has been suggested by consideration of several factors of plant physiology and of soil-plant interrelations, as well as by a limited number of direct experiments.

Jacobs (10) in 1931, reported an increase in growth of maple and elm trees when set out in a peat-soil mixture. In the same year, Tukey and Brase (17) found that peat mixed with the soil facilitated the rooting of layered apple and quince shoots. They reported (18) that additions of peat to a heavy loam soil used in planting apple trees resulted in greater root and top growth, especially in years when the rainfall was heavy in the early part of the growing season. In 1939, these authors (19) obtained somewhat similar results with apple trees planted in boxes containing the same heavy loam soil, and Brase (8) corroborated their results with roses under similar conditions.

Explanations of the effects of peat or other sources of organic matter upon the rooting and growth of plants have usually been given in general terms. It is sufficient at this time to point out that as a result of their presence or decomposition they supply certain plant nutrients and tend to cause changes in the physical characteristics of soils, which are frequently thought to be beneficial. Among the latter effects are improved tilth, aeration, and moisture relations. These factors have seldom been specifically related to the growth of young trees. Tukey and Brase (19), however, reported that the growth of newly planted apple trees was correlated with increased aeration of the soil, as influenced by admixture of peat and by excess water content.

It is also possible that any value of organic matter additions to the soil for the growth of newly planted trees may be due, at least in part, to growth-promoting substances which may be thus made available to the plants. In 1914, Bottomley found that composted peat contained a substance which stimulated the growth of wheat seedlings in cultures and stated that "the growth stimulating action of bacterized peat might be due to the presence of substances similar in nature to the accessory food bodies concerned in animal nutrition" (7, p. 532). Zimmerman, as a result of studies on the rooting of cuttings, said that "there seem to be some stimulating elements in peat which do not occur in sand" (21, p. 225). This possibility was also alluded to by Tukey and Brase (18), in studying the growth of young trees. Recent discoveries that

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certain substances stimulate the growth of root initials has provided means of investigating these hypotheses.

In 1936, vitamin B_1 (thiamin chloride) was shown by Kögl and Haagen-Smit (11) to promote the growth of plant embryos, and, in 1937, to be a specific root-growth-promoting substance by Bonner (2) and by Robbins and Bartley (14). This vitamin has been found in soils by Lilly and Leonian (13). Bonner and Greene (5) reported that certain manures contain appreciable quantities of vitamin B_1, and suggested that manures may be effective partly because of their content of this substance. In 1938, the addition of nicotinic acid to solutions containing vitamin B_1 was shown (1, 3) to further stimulate the growth of excised pea root tips, and the following year it was found (4) that excised root tips of some, but not all, species of plants respond to this substance in the presence of vitamin B_1.

The object of the experiments reported in this paper was to determine, under one set of conditions, the effects on growth of various kinds of organic matter applied to soil in which Valencia orange trees were planted, and also the effects of vitamin B_1 and nicotinic acid solutions applied to the soil about such young trees. The conditions of the trials minimized the importance of certain factors associated with the use of the bulky organic materials mentioned, namely, their effects on mineral nutritional deficiencies, moisture relations, and aeration.

Procedure

In this experiment the soil about young Valencia orange trees was treated with various kinds of organic materials at time of planting. These materials were used in two ways: they were mixed with the fill-back soil or were applied on the soil surface about the newly planted trees. Other treatments involved repeated applications of vitamin B_1 and nicotinic acid, alone and in combination, in the irrigation water. Irrigation of all trees was performed uniformly as required, and deficiencies of nitrogen and zinc were prevented or remedied as they occurred.

The nature of the soil, as well as the excellent growth of the trees during two seasons of observation were indications that soil aeration and other noncontrolled environmental conditions were satisfactory for tree growth. Records of tree growth were obtained over the growing seasons of 1939 and 1940 and are used to evaluate the effects of the various treatments.

The Valencia orange trees used in the trials were of selected stock, the scions being from one tree, budded apogamic sweet-orange seedlings. The nursery trees were not especially uniform. The experiment was planned in the randomized block design, and there were six blocks. Each plot contained two trees. Five of the blocks were planted with balled trees. The balls were 10.0 to 14.5 inches long and 8.25 to 9.9 inches in diameter. One block was planted to bare-root trees. The bare-root trees were planted with vertical roots about 18 inches deep and lateral roots as much as 12 inches in length.

The land in which the trees were planted is adjacent to the nursery. The soil is closely related to the Greenfield series and is of a slightly sandy loam texture. It is a deep, recent alluvial soil of granitic origin,

very slightly differentiated, and is relatively uniform. The mean moisture equivalent of this soil, in the first foot, is 14.3 per cent; drainage is considered very good; and the reaction is about pH 7.4 at the sticky point. Although it is one of the best citrus soils in southern California, it is low in nitrogen. The land had previously been in nursery and fertilized sparingly; it had recently been uniformly cover-cropped. The irrigation water has a pH of about 7.9.

All trees were cut back to four to six shoots, about 5 inches long, before digging. Bare-root trees were quickly planted after digging, and precautions were taken to prevent drying. All leaves on such trees were removed at the petiole. The leaves remaining on balled trees were cut off about two-thirds of the way to the petiole from the tip, and the trees were held 4 or 5 days in a lath house between digging and planting dates. Balled trees were planted 1 to 3 inches above their level in the nursery. Their burlap wraps were kept intact, except over the top of the ball, but all twine was removed. Planting was done in all cases in round holes, 24 inches in diameter and 18 inches deep. Water was applied to settle the fill-back soil.

The organic materials used for some of the treatments were imported, moistened, sphagnum peat moss, local sedge peat, and dairy manure. Certain characteristics of these materials are presented in Table I.[2]

Each of these organics was applied in two ways: (a) in basins, 3 feet in diameter, about the newly planted trees; and (b) mixed with the fill-back soil used in planting the trees. The materials were used in such quantities as to supply equal amounts of dry organic matter per tree. The quantities used were based upon and equivalent to the amount of loose, moist, sphagnum peat moss required to fill the tree holes one fourth full. Data on the amount of organic material used per tree are given in Table II. After the trees were planted, round basins 3 feet in inside diameter were made about each tree.

Additional treatments involved the use of vitamin B_1 (thiamin chloride, Merck) in solution in the irrigation water, in concentrations of 0.05 parts per million, and nicotinic acid in concentrations of 0.5 parts per million. These growth substances were used both separately and together at the concentrations noted.

Planting was done May 2 and 3, 1939. The first irrigation with

TABLE I—DESCRIPTION OF ORGANIC MATERIALS AS APPLIED

Material	Wet Basis (Per Cent)			Milliequivalents Per 100 Grams of Wet Material		
	Loss on Drying at 105 Degrees	Loss on Ignition	Ash	Cl	SO_4	pH*
Imported peat moss	74.0	25.4	0.6	Trace	1.0	3.3
Local sedge peat	62.4	21.4	16.2	Trace	9.6	3.5
Dairy manure, lot 18	28.3	49.8	21.9	25.4	15.6	8.9

*At 1:2.5 Material: water ratio.

[2]The authors are indebted to S. M. Brown, A. R. C. Haas, and D. S. Curtis for chemical and physical analyses.

TABLE II—AMOUNT OF ORGANIC MATERIAL USED PER TREE IN CERTAIN TREATMENTS

Description	Cubic Feet	Organic Matter (Grams)	Weight of Material (Grams)
Imported peat moss	1.13	170.9	6,728
Local sedge peat	0.67	170.9	7,983
Manure	0.31	170.9	3,431

water and solutions of growth substances occurred during planting of bare-root trees and immediately after planting of balled trees. Thereafter, the trees were irrigated at intervals of 2 weeks during the remainder of the arid season. There were 15 irrigations in 1939. Trees receiving the growth substances were treated with these substances in solution at the concentrations mentioned in the water at the first 13 irrigations. The first irrigation at time of planting required 20 gallons of water or solution per tree. The next two required only 10 gallons per tree. Subsequent irrigations during 1939 were of 20 gallons of water or solution per tree. Two late fall irrigations of water alone were applied to all trees. The last irrigation of the season occurred November 4, 1939, and was followed by well distributed seasonal rains.

During 1940 an increase in the amount of water applied was necessary to maintain satisfactory soil moisture. Two early applications of water only were uniformly applied in April and early May at the rate of 25 gallons per tree. On May 16, 1940, the growth substances were added at the stipulated concentrations to the irrigation water used for certain treatments, and 25 gallons of water or solution were used. The size of the irrigation basins was then increased to a diameter of 6 feet, without disturbing the soil in the bottoms of the original basins, and irrigations were applied at intervals of 2 weeks during the rest of the season. Thirty-three gallons of water or solutions were applied at the next irrigation. It then became impractical to irrigate with tank wagon, and water was conveyed in furrows to the basins, where it was applied at an estimated rate of 40 gallons of water per tree. To the trees receiving them, fresh stock solutions of vitamin B_1 and nicotinic acid were mixed with the water as it flowed into the basins, in quantities to supply these substances at the desired concentration. In all, 10 applications of growth substances were made during the irrigation season of 1940.

During the two seasons, weeds were removed by scraping the bottoms of the basins without disturbing the soil. Nutritional deficiencies were prevented or eliminated. Nitrogen was supplied in the irrigation water used in 1939, through the addition of calcium nitrate to provide 10 parts per million nitrogen at each of 13 irrigations. In the spring of 1940, the trees, uniformly, developed symptoms of mild nitrogen deficiency. This was corrected by application in the basins before the first irrigation of 25 grams of calcium nitrate per tree. In 10 subsequent irrigations Uramon was applied at a rate of 10 grams per tree. During January, 1940, symptoms of zinc deficiency also developed in all trees, irrespective of treatment. These symptoms were eliminated by treatment with a spray of zinc sulfate and soda ash, applied Jan-

uary 23, 1940. The trees were not pruned after planting; and no pest control measures were necessary, other than two treatments with nicotine sulfate for aphis in April, 1940. One tree was lost as a result of root decay.

Results

Growth of the trees was satisfactory in both 1939 and 1940. Although size differences between treatments were never visible, critical comparisons were obtained by measurements of trunk circumference, converted to area of cross section, at a marked point 6 inches above the bud union. Measurements were made on May 18, 1939, soon after planting the trees; on November 14, 1939, after the first season of growth; and on October 28, 1940, at the end of the second season of growth. Mean values of areas of cross sections were obtained for trees of each plot and subjected to study.

The size of orange trees at planting time has been shown by Webber (20) to be correlated with their size in subsequent years. The measurements obtained in the fall of 1939 and the fall of 1940 were therefore adjusted by covariance (9) on the original measurements of May, 1939. The mean unadjusted and adjusted values for each treatment are given in Table III; and for each block, in Table IV. It will be observed that at the end of the first and second seasons of growth, the adjusted mean area of cross section for the untreated trees (check) is slightly less than the adjusted means of most treated trees, especially those receiving vitamin B_1 and nicotinic acid. The reliability of these differences in size was studied by means of the analysis of variance of the adjusted yields. The analysis of tree size on November 14, 1939, appears in section I of Table V.

It will be noted from the value of F (16) that significant differences (at the 5 per cent level of significance) between mean areas of cross section of treatments and of blocks occur in the *unadjusted* measurements at the end of the first season. Upon adjustment for original size

TABLE III—Mean Area of Cross Section of Trunks of Trees on Various Dates, Unadjusted and Adjusted by Covariance, in Square Centimeters

Treatment	Unadjusted			Adjusted on Data of May, 1939		Adjusted on Data of November, 1939
	May 18, 1939	November 14, 1939	October 28, 1940	November 14, 1939	October 28, 1940	October 28, 1940
Check	3.65	4.88	11.99	4.84	11.95	12.07
Vitamin B_1	4.04	5.16	13.59	4.75	13.21	13.34
Nicotinic acid	3.81	5.25	13.92	5.06	13.73	13.57
Vitamin B_1 and Nicotinic acid	3.88	5.75	14.02	5.48	13.78	13.10
Imported peat moss in basins	3.91	5.32	13.15	5.03	12.88	12.73
Local sedge peat in basins	3.01	4.34	11.71	4.90	12.23	12.41
Manure in basins	3.33	4.78	13.06	5.04	12.30	13.25
Imported peat moss mixed with fill-back	3.39	4.49	11.91	4.69	12.10	12.44
Local sedge peat mixed with fill-back	3.64	5.05	12.46	5.01	12.43	12.35
Manure mixed with fill-back	3.37	4.46	12.64	4.68	12.84	13.20

TABLE IV—MEAN AREA OF CROSS SECTION OF TRUNKS OF TREES IN VARIOUS BLOCKS, UNADJUSTED AND ADJUSTED BY COVARIANCE, IN SQUARE CENTIMETERS

Block No.	Method of Planting Trees	Unadjusted			Adjusted on Data of May, 1939		Adjusted on Data of November, 1939
		May 18, 1939	November 14, 1939	October 28, 1940	November 14, 1939	October 28, 1940	October 28, 1940
1	Bare root	3.09	4.29	11.62	4.78	12.08	12.38
2	Balled	3.67	4.97	13.45	4.91	13.39	13.42
3	Balled	3.82	5.17	13.22	4.97	13.02	12.96
4	Balled	3.65	5.06	12.88	5.02	12.85	12.76
5	Balled	3.65	4.96	12.27	4.91	12.23	12.26
6	Balled	3.74	5.24	13.62	5.11	13.51	13.29

differences of the trees, however, the significance of differences between means of treatments and of blocks is reduced below the 5 per cent level. Apparently none of the soil treatments produced significant effects in the first growing season. The analysis also shows that no significant differences in size existed at the end of the first season between trees planted with bare roots and balled roots.

A similar analysis of tree size on October 28, 1940, is given in section 2 of Table V. The study indicates that no significant differences in mean sizes resulted from different soil treatments over the two seasons, before or after adjustment. Photographs of representative trees in certain treatments are shown in Fig. 1. The mean sizes of trees in the various blocks did differ significantly (5 per cent level) *before* adjustment, but not when adjusted for size of the trees at time of planting.

These indications of lack of response to any of the treatments in the second season of growth are more clearly evident when the size measurements for October, 1940, are adjusted by covariance on the tree

TABLE V—ANALYSIS OF VARIANCE AND COVARIANCE OF AREA CROSS SECTION AT VARIOUS DATES

Source of Variation	Unadjusted Values					Adjusted Values of Y		
	Degrees of Freedom	Mean Squares		F		Degrees of Freedom	Mean Squares	F
		X	Y	X	Y			
1. Measurements of May 18, 1939, = X. Those of November 14, 1939, = Y								
Blocks.......	5	0.6858	1.1564	2.11	2.48*	5	0.1148	1.60
Treatments...	9	0.6239	1.1748	1.92	2.53*	9	0.3293	1.79
Error........	45	0.3256	0.4651	—	—	44	0.1836	—
2. Measurements of May 18, 1939, = X. Those of October 28, 1940, = Y								
Blocks.......	5	0.6858	5.8981	2.11	2.86*	5	3.1767	1.71
Treatments...	9	0.6239	4.2102	1.92	2.04	9	2.4311	1.31
Error........	45	0.3256	2.0621	—	—	44	1.8539	—
3. Measurements of November 14, 1939, = X. Those of October 28, 1940, = Y								
Blocks.......	5	1.1564	5.8981	2.48*	2.86*	5	2.0862	1.41
Treatments...	9	1.1748	4.2102	2.53*	2.04	9	1.3138	1.12
Error........	45	0.4651	2.0621	—	—	44	1.4746	—

*Significant at 5 per cent level.

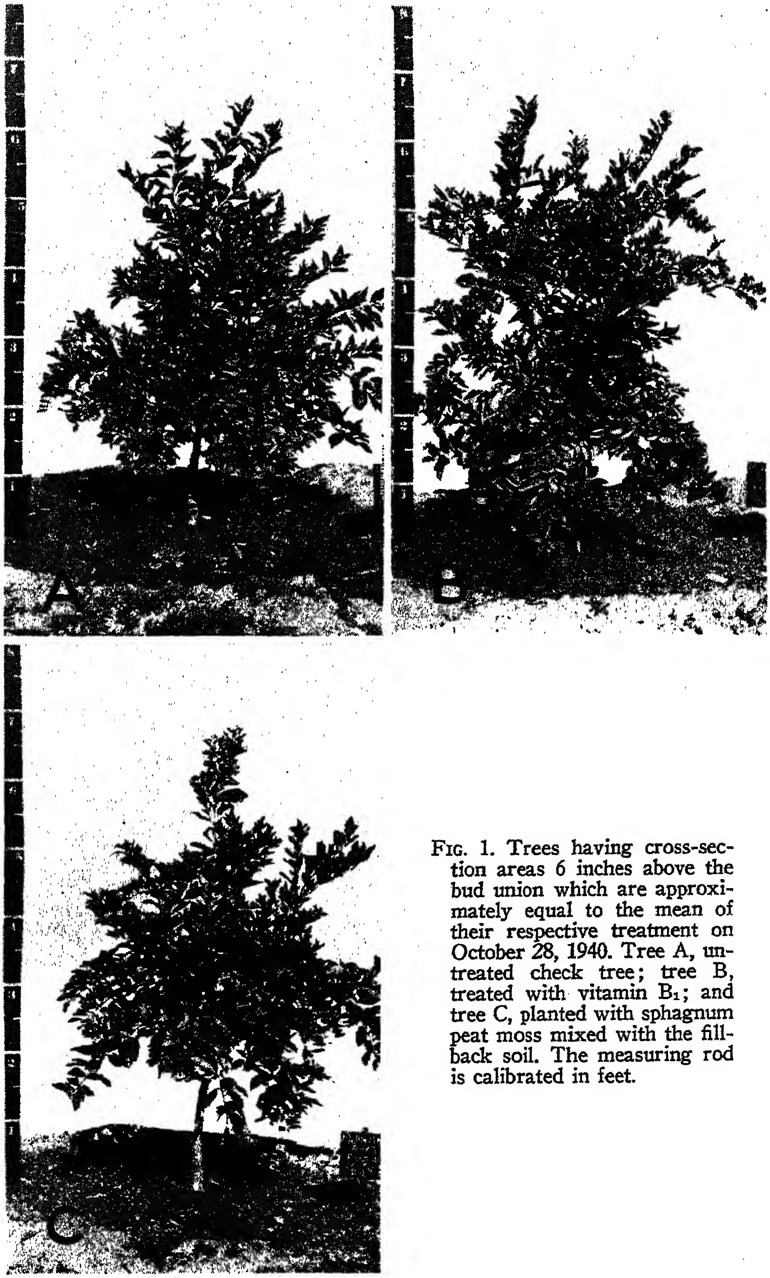

FIG. 1. Trees having cross-section areas 6 inches above the bud union which are approximately equal to the mean of their respective treatment on October 28, 1940. Tree A, untreated check tree; tree B, treated with vitamin B_1; and tree C, planted with sphagnum peat moss mixed with the fill-back soil. The measuring rod is calibrated in feet.

sizes in November, 1939. The mean values for the treatments and blocks so adjusted are presented in the last columns of Tables III and IV. An examination of these data and of the analysis of variance and covariance given in section 3 of Table V, leaves no doubt as to the nonsignificance of differences in size occurring in the second season of growth as a result of the treatments or methods of planting.

In view of the lack of significant response of the trees under the conditions of this experiment to either organic matter or to the growth promoting substances, assays of vitamin B_1 content of leaves were made using the *Phycomyces* test (15). Twenty mature leaves of the spring cycle of 1940 were selected from each tree in each plot of certain treatments about December 1, and the leaves from the two trees of one plot were lumped together. All the leaf samples were then dried at 60 to 70 degrees C in a current of dry air and were ground in a Wiley mill. Vitamin B_1 determinations were made on duplicate 10-milligram samples. Two duplicate determinations of the recovery of a known amount of vitamin B_1 in the presence of 10 milligrams of the orange leaf tissue were also made. Seventy per cent of the added vitamin B_1 was recovered in one case and 72 per cent in the second case. The assumption was therefore made that only 71 per cent of the vitamin present in the leaves themselves was recovered by the *Phycomyces* assay. The results showed that the mean vitamin B_1 content of the sampled leaves was as follows, in gamma per gram of dry weight:

Leaves from check trees	8.01
Leaves from trees treated with vitamin B_1	7.86
Leaves from trees treated with sphagnum peat in fill-back soil	7.59
Leaves from trees treated with manure in fill-back soil	7.96

The differences in leaf vitamin B_1 content, as between treatments, are small and are all nonsignificant, when judged by analysis of variance. It should be noted that the vitamin B_1 content of all orange leaves was relatively high, as compared with that of other species, such as *Camellia*, which have been reported by Bonner and Greene (6) as responding to vitamin B_1 treatment. This comparison and the results of the growth experiment indicate that young vigorous Valencia trees at Riverside synthesize sufficient vitamin B_1 for their own needs.

The manure and the two peat samples used in this experiment were found to contain appreciable quantities of vitamin B_1. For the manure and imported peat moss, assays indicated 2.7 parts per million, dry weight basis. Quantitative determinations of the vitamin B_1 content of the local peat could not be made owing to the presence of unidentified interfering substances, but it appeared that more than 1 part per million was present. The failure of the leaf analyses to reflect the application of vitamin B_1 from the organic materials, and also as a solution of thiamin chloride, appears to be analogous to the failure of whole grain to vary in vitamin B_1 content when produced on fields fertilized in various ways, as reported by Leong (12).

Summary

Vigorous young Valencia orange trees, planted at Riverside with bare and balled roots in a good soil in which drainage was satisfactory, and provided with deficient mineral elements and water, failed to show a significant growth response over two growing seasons to the use of organic matter, vitamin B_1 or nicotinic acid. The organic matter consisted of two kinds of peat and dairy manure and was applied in the fill-back soil at time of planting or as a surface mulch after planting. The growth-promoting substances were repeatedly applied in solution in the irrigation water. The vitamin B_1 content of mature leaves at the end of the second growing season was not affected by any of the soil treatments. In all cases it was higher than that of species of plants which have been reported to respond to treatment with vitamin B_1. It appears that vigorous, young Valencia orange trees, grown at Riverside, synthesize sufficient vitamin B_1 for their own needs, and that the beneficial effects sometimes reported as resulting from the use of organic materials at the time of planting trees are due to the factors which were not limiting under the conditions of this experiment. Trees planted with bare roots grew equally as well as trees planted with balled roots.

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Effect of Mulching Materials on Moisture Loss From Soils[1]

By L. M. Turk and N. L. Partridge, *Michigan State College, East Lansing, Mich.*

THE use of mulches in orchards in Michigan is a recommended practice. Mulches are believed to be beneficial chiefly through their influence on soil moisture relationships. However, detrimental effects have been observed with their use under certain conditions. Observations have been made which indicate a nitrogen deficiency in soils where carbonaceous mulching materials have been used, especially on soils low in organic matter. On the other hand, fruit has failed to mature properly and develop desirable color where nitrogenous mulching materials have been used; this has been particularly noticeable on the more fertile soils. In the fall of 1939, an experiment, involving the use of lysimeters, was started primarily for the purpose of studying the effect of different kinds of mulching materials on the accumulation of soil nitrates. This experimental arrangement offers an excellent opportunity to study the effectiveness of the different mulches on the conservation of soil moisture, and it is to this phase of the work that this preliminary report is devoted.

Moisture is perhaps the greatest limiting factor in fruit production in Michigan, particularly on the more sandy soils and where a sod culture system is used. It is a recommended practice, in orchards in permanent cover, to use some sort of mulching material around the trees. Just how effective these mulches are in controlling or increasing the amount of available soil moisture is a question that is frequently raised. The idea is sometimes expressed that certain kinds of mulches intercept and absorb such a large share of the rainfall that less water is actually available for the fruit plants than without the mulch. In other words, the absorption and subsequent evaporation of moisture from the mulch may be greater than the reduction in loss of water from the soil by evaporation. Data are presented in this report relative to these problems.

Methods

Cylindrical lysimeters, 40 inches in diameter and 15 inches deep, of galvanized iron coated with asphalt paint were used. About 7 inches of surface soil were placed in each lysimeter and the walls permitted to extend far enough above the soil to keep the mulch in place and prevent the loss of water by run-off. Three soil types of three different classes (Coloma sand, Hillsdale sandy loam, and Miami silt loam) were used. Mulches of alfalfa hay, straw, and straw plus ammonium sulphate were applied to each of the three soils; other lysimeters received no mulch and weeds were kept out by frequent cultivation. Additional mulches of peat, shredded corn stover, shredded corn stover

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with ammonium sulphate, sawdust, shavings and gravel were used on the Hillsdale sandy loam soil. The coarse mulching materials (alfalfa hay, corn stover, and straw), were about 5 inches thick and the other materials (shavings, sawdust, pulverized peat and gravel) were about 1 inch in thickness. Each treatment was made in triplicate. Determinations were made of the quantity of water percolated through each lysimeter, as governed by the frequency, intensity, and duration of the rainfall.

Results

Data for the losses in soil moisture for the fall of 1939 and for 1940 up to October 24, are presented in Table I. The data are expressed in terms of pounds of water and each figure represents the average of three lysimeters. The readings actually represent the total quantity of rainfall less the amount of water absorbed by the soil and mulch and that lost by evaporation. The treatments are listed in the tables for each soil in the order of decreasing amounts of percolate for the entire period.

In this discussion, the quantity of percolating water is used as an indication of the effectiveness of each treatment in increasing the amount of available water; the greater the amount of percolate the more effective is the mulch. The data show very strikingly the pronounced effect that mulching materials have on increasing the quantity of available water, with the possible exception of pulverized peat. Except for the peat mulch, about twice as much or more than twice as much percolate was collected from the mulched soils as from the nonmulched soils.

No significant differences are noted in the effectiveness of straw, straw plus ammonium sulphate, and alfalfa hay mulches on either of the three soils. Furthermore, it may be of interest to point out that the mulches were essentially as effective on one soil as the other.

In considering the results obtained with the Hillsdale sandy loam soil, it is to be pointed out that pulverized peat was ineffective in increasing the quantity of percolate; results were very similar to those obtained with no mulch. The other mulching materials were decidedly effective in increasing the amount of available water. Under the conditions of this experiment, the amount of water absorbed by these mulching materials, here considered as unavailable, was more than compensated by the reduction in the amount of evaporation due to their use. The data are not sufficient to justify any attempt to compare the relative value of these materials because the differences are not very great; although from this point of view gravel, sawdust and shavings appear somewhat superior to straw, alfalfa, and corn stover.

It is to be noted that during periods of light rainfall no percolate was collected from the unmulched soils or from the Hillsdale soil with peat mulch. At the same time considerable quantities of percolate were collected from the soils with mulching materials other than peat. This, it would seem, gives emphasis to the value of effective mulches during the dryer seasons of the year, particularly on the more droughty soils.

TABLE I—AVERAGE NUMBER OF POUNDS OF PERCOLATE COLLECTED FROM LYSIMETERS FILLED WITH HILLSDALE, WITH MIAMI, AND WITH COLOMA SOILS

	Oct 30–Nov 12	Nov 13–Dec 5	Total Oct 30–Dec 5	Apr 10–Apr 18	Apr 19–May 3	May 4–May 19	May 20–May 26	May 27–May 30	Total Apr 10–May 30	Jun 24–Jun 28	Jun 29–Jul 11	Jul 12–Aug 6	Aug 7–Aug 20	Total Jun 24–Aug 20	Aug 30–Sep 2	Sep 3–Sep 25	Sep 26–Oct 7	Oct 8–Oct 14	Oct 15–Oct 24	Total Aug 30–Oct 24	Total For The Four Periods
Rainfall, (Inches)	0.65	0.73	1.38	0.71	1.10	1.16	0.83	1.11	4.91	0.70	1.63	1.27	1.04	4.64	1.06	1.11	1.82	1.19	0.29	5.47	16.40
In Pounds Water per Lysimeter	29.5	33.1	62.6	32.2	49.9	52.6	37.6	50.3	222.6	31.7	73.9	57.6	47.2	210.4	48.1	50.3	82.6	54.0	13.1	248.1	743.7
Hillsdale Soil																					
Gravel	21	24	45	28	30	27	28	46	159	30	24	20	8	82	31	18	47	27	8	131	417
Sawdust	14	22	36	20	28	22	26	47	143	26	25	25	9	85	30	21	35	37	18	141	405
Shavings	13	22	35	20	29	21	26	47	143	26	24	30	12	92	30	18	43	30	12	133	403
Straw + N	5	14	19	29	19	15	21	37	121	26	24	32	15	97	30	23	48	27	7	135	372
Straw	2	12	14	26	19	12	20	43	120	24	21	29	14	88	32	19	48	25	7	131	353
Alfalfa	5	12	17	26	21	11	20	43	121	27	21	23	11	82	31	17	48	26	7	129	349
Stover	10	9	19	17	19	19	24	47	126	27	20	20	10	77	30	17	48	24	7	126	348
Stover + N	9	9	18	17	19	21	25	44	126	29	21	14	7	71	30	13	47	25	6	121	336
Peat	5	6	11	9	10	0	0	32	51	13	0	0	0	13	26	0	37	19	4	86	161
No mulch	9	9	18	16	0	0	0	20	36	15	0	0	0	15	28	0	32	22	4	86	155
Miami Soil																					
Straw	7	15	22	28	19	14	21	46	128	25	22	29	16	92	30	22	47	28	7	134	376
Straw + N	6	14	20	34	20	13	19	40	126	26	22	30	16	94	30	23	48	27	7	135	375
Alfalfa	7	15	22	23	21	15	21	40	120	28	20	23	14	85	30	19	48	28	7	132	359
No mulch	10	8	18	22	0	0	1	26	49	14	0	0	0	14	27	0	48	21	3	99	180
Coloma Soil																					
Straw + N	5	15	20	22	21	12	21	41	117	25	22	27	16	90	30	24	47	28	7	136	363
Alfalfa	8	17	25	22	23	14	22	38	119	24	22	10	17	73	28	22	47	26	7	130	347
Straw	6	15	21	17	17	10	19	35	98	23	20	24	15	82	29	23	48	29	5	134	335
No mulch	12	11	23	19	4	0	0	15	38	13	0	0	0	13	28	0	41	24	4	97	171

Discussion

In considering the movement of moisture through the lysimeters, it is obvious that no large amount of water could move through the mulch into the soil until the mulch approached saturation, nor could drainage water appear until the soil had reached its moisture holding capacity unless cracks or other non-capillary passageways had developed through the soil. During periods between rains evaporation occurred from both the mulch and soil and it is necessary that this evaporated moisture be replaced before further percolation. Thus, the amount of percolation is appreciably influenced by the quantity, intensity, and frequency of the rains, the climatic factors affecting evaporation, and the effectiveness of the mulch in decreasing evaporation losses.

The results obtained with peat seem particularly significant. Apparently the peat had such a great absorptive capacity for water that with light rains or with long intervals between rains very little water actually reached the soil or at least not enough to permit percolation through the soil. Under these conditions evaporation of water from the mulch itself was enormous. As evidence to support this contention, it is observed that gravel was the most effective of all the mulching materials used.

In considering these results in relation to the roots of fruit trees growing under these sytems of soil management it is not correct to assume that the quantities of percolate represent the exact differences in the amounts of available moisture to the roots of trees. There is usually a large accumulation of roots in the surface soil immediately beneath the mulch or perhaps in the mulch itself and moisture would be available which would not be indicated by the relative differences in the amount of percolate obtained under the conditions of this experiment.

These preliminary results definitely indicate the value and effectiveness of mulching materials in the conservation of moisture under Michigan conditions. This is of particular importance in those orchards located on the more sandy or droughty soils, since soil moisture is without doubt one of the greatest limiting factors in fruit production under such conditions.

Relation of Weather to Prevalence of Internal Cork in Apples

By L. P. Latimer, *University of New Hampshire, Durham, N. H.*

ANTICIPATING criticism for presenting a topic which betokens a step backward into the stream of scientific progress, a word of explanation seems necessary.

The disease internal cork of apples (using the nomenclature suggested by Bailey and Thies (1)) has been observed occasionally in New Hampshire as well as the rest of New England. The writer (3) apparently was the first to report in a scientific journal the serious economical importance of this disease to apple growers of this state.

Following the discovery that boron deficiency is the direct cause of internal cork and related diseases, borax was applied in 1937 to a few badly affected trees in certain orchards. Freedom from internal cork of the fruit of these treated trees in 1939 demonstrated the value of this treatment so well that growers were quick to apply borax to their orchards. Thus the opportunity to study factors affecting boron deficiency in the field has been nearly precluded. In New Hampshire boron deficiency of apples manifests itself primarily as internal cork. External cork is of less common occurrence. Dieback and rosette are seldom encountered.

In New Hampshire orchards boron deficiency symptoms usually follow conditions that cause excessive drying of the soil.

Although Mix (4) in 1916 realized that the direct cause of cork diseases was unknown at that time, he considered drouth the predisposing factor. Since then others have also recognized the relation of drouth to the occurrence of such troubles, but have summarily disposed of the topic or made statements concerning rainfall and other climatic factors unsupported by data.

The purpose of this paper is to present the results of observations concerning the effect of weather conditions on the occurrence and prevalence of internal cork in susceptible localities of New Hampshire. It is hoped that this data will help to clarify this relationship.

Relation to Drouth

In years when normal or excess rainfall occurs generally throughout the apple districts, internal cork has not been reported. In other years only those parts of the state receiving deficient rainfall were affected.

Mix (4) described marked prevalence and severity of cork (presumably identical with internal cork) in 1914 in Clinton County, New York. He associated this condition with the extended drouth which continued through the months of May, June and July of that year. In 1915 rainfall was deficient in May and June, but was above normal in July and August. Cork was prevalent in that year. In 1916 rainfall was nearly normal in May and June, and cork prevailed only with trees badly diseased in the past. Bailey and Thies (1) correlated the marked prevalence of internal cork in 1936 at Amherst, Massachusetts, with a cumulative 5 inch deficiency of rainfall in May, June and July. Burrell

(2) stated that cork occurred in 1933 in the vicinity of test plots and that rainfall was below normal in June and July, but above normal in April, May and August.

In New Hampshire internal cork was observed more or less generally in 1929, 1936 and 1939, and in some sections in 1932 and 1933.

Table I shows the average departure from normal rainfall during the spring and summer months of the years that observations on the occurrence of internal cork are available. Averages are based on weather records of three widely different apple sections where internal cork has been known to occur. Durham represents the southeastern, Plymouth the north central and Nashua the south central districts. In 1929 there was a mild outbreak, most severe in the south central section. In 1933 conditions were somewhat reversed, the outbreak being especially

TABLE I—DEPARTURE FROM NORMAL RAINFALL, AVERAGE OF THREE STATIONS, PLYMOUTH, DURHAM, AND NASHUA, NEW HAMPSHIRE

	April	May	June	July	August	September
			Years When Internal Cork Was Prevalent			
1929	1.81	.56	– .58	–2.20	–1.15	–1.63
1932*	–1.43	–1.82	–1.13	–1.42	.26	3.68
1933**	2.73	–1.44	–1.86	–1.90	1.44	1.90
1936	.71	– .98	–1.20	– .67	.04	–1.74
1939	1.39	–1.00	– .58	–1.35	.47	–1.32
			Years When Internal Cork Was Not Prevalent			
1927	–2.24	– .32	–1.80	1.63	1.68	.09
1928	.84	– .06	.61	1.46	1.48	– .66
1930	–1.60	– .33	– .04	1.06	– .48	–2.53
1931	– .41	.64	1.96	– .10	1.10	– .41
1932*	.60	–1.78	–1.16	1.77	.36	1.51
1933**	9.20	– .88	–1.54	1.24	.93	.67
1934	1.43	.36	.73	– .10	–1.93	4.55
1935	– .31	–1.29	3.25	– .81	–1.70	1.67
1937	.93	1.34	1.58	–1.51	– .08	– .11
1938	– .55	.33	1.43	5.67	– .89	5.68
1940	1.55	1.60	– .10	1.84	–2.17	——

*No internal cork reported in the north district.
**No internal cork reported in the southeast district.

severe in the region around Plymouth, moderate in the south central part, and none being recorded in the southeastern district. A moderate outbreak, severe in a few localities, occurred in 1936. In 1939 the southern sections were moderately to severely affected, the northern section being affected to a lesser degree. Table I shows that rainfall was deficient for the four months April to July inclusive of 1932 in affected sections, while in the unaffected northern section drouth existed only in May and June. In 1933, however, the drouth was more severe in the north and central apple districts, severe drouth occurred in May, June and July while in Durham May and June alone were drouthy.

Table II shows the average departure from normal rainfall for all three stations and for individual months. This data shows that since 1926 the rainfall in April has averaged above normal both for years when internal cork was and was not prevalent, the difference not being large enough to be considered significant. Table III shows that during this period rainfall deficiency actually occurred more often in years

TABLE II—DEPARTURE FROM NORMAL RAINFALL, AVERAGE ALL OBSERVATIONS

	Years Internal Cork Prevalent	Years Without Internal Cork	Difference	S. E.
April	1.10	.30	.80	.53
May	− .83	.13	− .96*	.34
June	−1.00	.69	−1.71*	.39
July	−1.45	1.05	−2.50*	.48
August	.17	− .27	.44	.45
September	.23	.98	− .75	.85

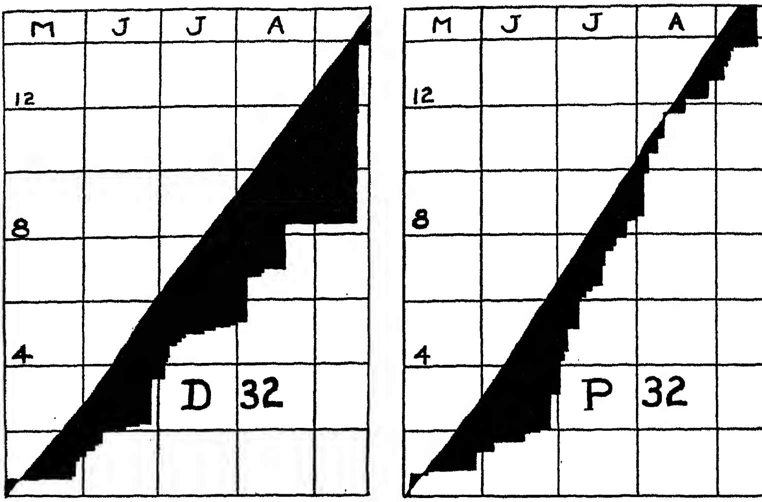
*Highly significant.

when internal cork was not prevalent than in years of prevalence. The tendency becomes stronger for internal cork to occur during years when rainfall is deficient in May, yet in years free from the trouble 50 per cent were also dry in May. June and July seem to be the most critical months and in every case where internal cork was prevalent rainfall was deficient in both June and July. During the past 14 years internal cork has never been prevalent when rainfall was deficient in both months. August and September rainfall seem to have nothing to do with the prevalence of internal cork. From this it is evident therefore that during the past 14 years in New Hampshire the critical period that determines whether or not internal cork will be prevalent in apples is June and July together, but not either month alone.

TABLE III—PERCENTAGE OF OBSERVATIONS SHOWING RAINFALL DEFICIENCY

Month	Internal Cork Years	Non-Cork Years
April	15	48
May	77	52
June	100	34
July	100	38
August	38	62
September	77	34
April and May	15	28
May and June	77	21
June and July	100	0
July and August	38	28
August and September	31	14
April, May and June	15	17
May, June and July	77	0
June, July and August	38	0
July, August and September	31	3

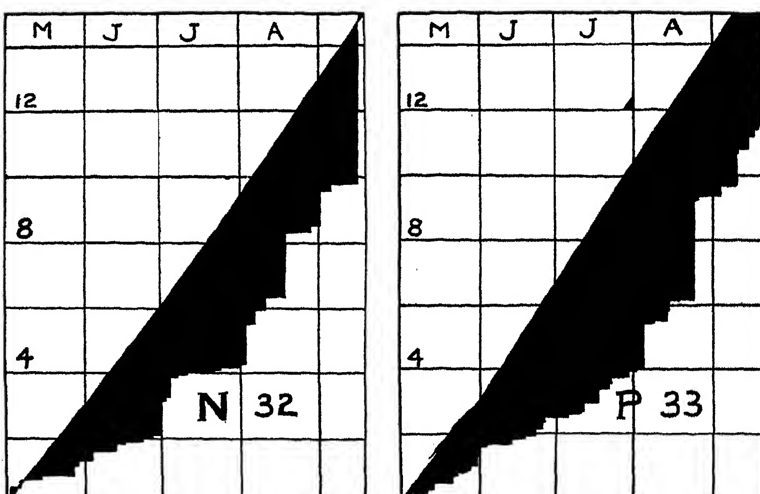
It might be possible for the total rainfall of June and July to be normal or above and yet have an extended drouth period during these two months. This would happen if heavy rain occurred near June 1 and July 31, and 8 weeks of drouth intervened. Monthly weather record summaries would not reveal this condition from total rainfall data alone. For this reason Figs. 1, 2, and 3 seem to present the prevailing moisture conditions in a better way by charting the cumulative departure from normal rainfall. This better indicates the drouth periods that undoubtedly exert a strong influence on the ability of the trees to obtain a sufficient quantity of boron for continued growth and cell division or development.



Durham, New Hampshire, 1932.
Some internal cork.

Plymouth, New Hampshire, 1932.
No internal cork reported.

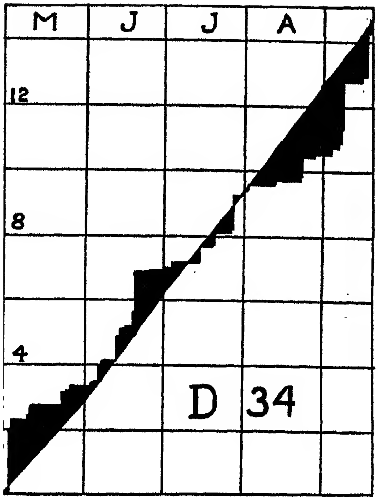
FIG. 1. Prevailing Moisture Conditions in Seasons and at Locations Indicated. Diagonal continuous lines represent cumulative normal rainfall after May. Angular lines represent actual cumulative rainfall after May 1.



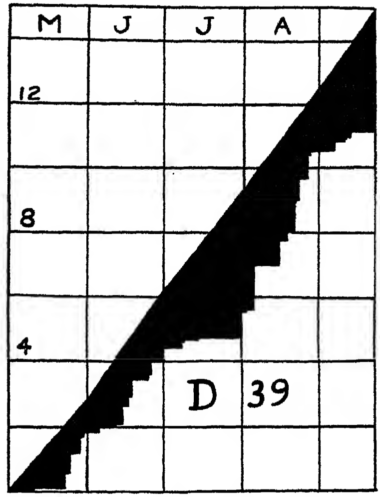
Nashua, New Hampshire, 1932.
Internal cork very prevalent.

Plymouth, New Hampshire, 1933.
Internal cork very prevalent.

FIG. 2. Prevailing Moisture Conditions in Seasons and at Locations Indicated. Diagonal continuous lines represent cumulative normal rainfall after May. Angular lines represent actual cumulative rainfall after May 1.



Durham, New Hampshire, 1934.
No internal cork reported.



Durham, New Hampshire, 1939.
Internal cork prevalent.

FIG. 3. Prevailing Moisture Conditions in Seasons and at Locations Indicated. Diagonal continuous lines represent cumulative normal rainfall after May. Angular lines represent actual cumulative rainfall after May 1.

Relation to Other Climatic Factors

Mix (4) stated that high winds were prevalent early in the season of years of drouth when cork was prevalent. Bailey and Thies (1) stated that the number of hours of bright sunshine, number of clear days and mean temperature were above normal and relative humidity below normal in 1936 in parts of Massachusetts where internal cork was prevalent. These conditions, they believed, would contribute to drying out of the soil and favor the prevalence of internal cork. They did not present information concerning these same climatic conditions in parts of the state where internal cork was not prevalent. Also, they considered only the one season, 1936.

A study of weather records for New Hampshire, Table IV, revealed the following facts with relation to the effect of climatic factors other than rainfall on the prevalence of internal cork.

Sunshine, wind and humidity records are for Concord, New Hampshire, the only station where these were available. Fortunately Concord is centrally located between the three stations where internal cork has been most fully studied.

The mean maximum temperature for the months of June, July and August was about the same for years in which internal cork was prevalent as for those when it was not. In July alone the mean minimum temperature was significantly lower in years of prevalence of internal cork than in other years. There is no indication that higher temperatures may commonly prevail in years of cork prevalence as reported by Bailey and Thies (1).

TABLE IV—Effect of Other Climatic Factors on Prevalence of Internal Cork

Climate and Location	Month	Years Not Observed	Years Prevalent	Diff.	S. E. Diff.	t for P = .05
Average maximum temperature Concord, N. H. (degrees F)	June	76.2	77.2	1.0	1.25	2.45
	July	81.5	80.9	-0.6	0.92	2.45
	August	79.1	79.8	0.7	1.71	2.45
Average minimum temperature Concord, N. H. (degrees F)	June	53.5	52.8	-0.7	1.01	2.45
	July	59.5	56.3	-3.2*	0.89	2.45
	August	56.7	56.3	-0.4	1.70	2.45
Average relative humidity Concord, N. H. 8 A.M. (per cent)	June	78.0	76.8	-1.2	2.68	2.78
	July	80.3	78.3	-2.0	2.22	2.78
	August	86.5	83.0	-3.5	2.46	3.18
Average relative humidity Concord, N. H. Noon (per cent)	June	59.5	59.5	0.0	—	—
	July	62.3	53.3	-9.0	4.03	2.78
	August	65.2	53.7	-11.5	4.71	3.18
Average sunshine (per cent of possible) Concord, N. H.	June	54.0	63.0	9.0	5.30	2.78
	July	54.5	61.7	7.2	2.63	3.18
	August	53.7	59.3	5.6	5.30	3.18
Average wind velocity Concord, N. H (miles per hour)	June	5.25	5.40	0.15	0.34	2.78
	July	4.53	5.20	0.67	0.43	3.18
	August	4.22	4.77	0.55	0.33	3.18
Average number clear days Plymouth, N. H.	June	13.7	18.0	4.3	2.21	2.45
	July	15.1	18.2	3.1	1.69	2.45
	August	17.2	16.4	-0.8	1.72	2.45
Average number clear days Durham, N. H.	June	15.2	17.8	2.6	1.26	2.45
	July	13.7	17.8	4.1	1.68	2.45
	August	17.2	17.2	0.0	—	—

*Highly significant.

Although there seems to be a tendency for the relative humidity to be slightly lower in July and August in years of cork prevalence, the differences observed are in no case large enough to be considered statistically significant. The same is true for sunshine, although the tendency seemed to be for slightly more hours of sunshine in cork prevalent years. The importance of all these other factors might possibly be better expressed from daily records as has been done with rainfall but such records are not available at the observation stations.

Considering the number of clear days, the tendency seems to be towards a slightly larger number of clear days in June and July of years when internal cork is prevalent, although differences are not quite large enough to be significant. In August there was no difference in the average number of clear days.

Wind velocity was apparently about the same for June, July and August, respectively, in years when internal cork was or was not prevalent.

In conclusion it seems apparent that climatic factors other than spring and summer rainfall have had slight influence if any on the prevalence or severity of internal cork in New Hampshire since 1926.

Extended drouth during June and July seems to be the one contributing atmospheric factor definitely responsible for the inability of the tree to obtain sufficient boron for complete or perfect development of the fruit. Most of the apple orchards of New Hampshire are located on soils ordinarily favorable for their development. The industry has

existed long enough so that unfavorable sites have already been abandoned and expert advice is usually sought before new plantings are made. Without doubt there are situations where the soil could not supply sufficient boron in any year and in the majority of places boron deficiency has not yet been detected in any year. Where internal cork has been reported in apple districts the trees are located on soils that can apparently supply sufficient boron only in years of normal or excess summer rainfall. The deficiency is readily overcome by applying borax or boric acid to these soils and the occurrence of internal cork thus prevented even in dry summers.

Although drouth in June and July seems essential to the development of internal cork in New Hampshire apples, the effect is intensified when drouth conditions are continued from the earlier spring months. Furthermore it does not seem that heavy rain following the summer drouth is a factor inducing internal cork to make its appearance.

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Periodicity in Transpiration of Lemon Cuttings Under Constant Environmental Conditions

By J. B. Biale, *University of California, Los Angeles, Calif.*

IN THE transpiration studies carried on at this laboratory and reported previously (1, 2) the plants were subjected to 12-hour light periods alternating with 12 hours of darkness. The exposure to artificial light was from 8:00 a.m. to 8:00 p.m., coinciding approximately with the daylight period in the greenhouse where the plants were grown prior to experimentation. Recently it was thought advisable to introduce shorter photoperiods of 4 hours alternating with 4 hours of darkness. While checking on the constancy of transpiration losses under these conditions some unexpected results were obtained which form the subject matter of this report.

Transpiration Losses During 4-Hour Light Periods

The materials and methods employed in these experiments were essentially the same as in previous ones (2). Eureka lemon cuttings were taken from three adjacent trees and planted in sand in the greenhouse on November 1, 1938. Each cutting had four or five leaves. The range in leaf surface for the 22 plants was from 1.07 to 2.58 square decimeters as measured by the planimeter method. At the time of these tests the root systems were well developed ranging from 388 to 855 milligrams of dry weight of roots per plant. In all cases the root-leaf ratio was much higher than 130 milligrams root dry weight per square decimeter of leaf surface, a value found in earlier work (2) to be the minimum for unhindered water absorption under conditions similar to the ones employed in these studies. On the basis of previous experiments a root temperature of 30 degrees C, a room temperature of 25 degrees C and 37 per cent humidity were employed throughout these tests. As a source of light 18 General Electric fluorescent globes of 15 watts each were used. They were suspended at a distance of 18 inches from the bath top and provided a light intensity of 400 to 500 foot candles as measured by a photronic cell at the plant level. This range in light intensity may account partially for the variations in water loss between plants. However, each cutting was placed in the same position during the entire experimental period, and therefore exposed to uniform light intensity.

The plants were brought from the greenhouse on May 6, 1939, sealed in the 1-quart jars containing nutrient solution, and placed in the control chamber on May 7, at 2:00 p.m. The lights were turned on for 4 hours at 4:00 p.m. Each photoperiod of 4 hours alternated with a 4-hour dark period. From May 7 until May 10 the light periods were: 12:00 to 4:00 a.m., 8:00 to 12:00 a.m. and 4:00 to 8:00 p.m. Table I presents the water losses per plant for each of these periods.

In examining the average as well as the individual values in Table I it can be clearly seen that the minimum water loss took place during the 12:00 to 4:00 a.m. period, though all conditions were exactly the same as during the other periods. The first transpiration determinations

TABLE I—Water Loss in Grams per Plant During 4-Hour Light Periods

Plant No.	Leaf Area (Sq. Dm.)	MAY 7	8			9			10	
		4 to 8 P.M.	12 to 4 A.M.	8 to 12 A.M.	4 to 8 P.M.	12 to 4 A.M.	8 to 12 A.M.	4 to 8 P.M.	12 to 4 A.M.	8 to 12 A.M.
1	1.86	1.95	1.35	2.05	2.80	1.20	2.40	3.40	1.45	2.45
2	1.70	1.70	1.35	1.80	2.00	1.25	1.65	2.00	1.20	1.70
3	1.75	2.30	1.60	2.55	3.05	1.70	2.95	3.15	1.65	2.60
4	1.42	1.65	1.55	1.95	2.25	1.30	2.20	2.55	1.35	2.05
5	1.81	3.05	2.05	3.05	3.45	2.05	3.10	3.25	1.80	2.75
6	1.63	2.80	2.25	3.20	3.70	2.40	3.30	3.70	2.10	3.10
7	2.54	3.00	2.50	3.40	3.95	2.40	3.45	3.80	2.10	3.25
8	2.15	2.10	1.55	2.60	2.90	1.80	2.60	2.85	1.50	2.50
9	1.98	2.25	2.10	2.85	3.35	2.25	3.30	3.45	2.20	3.45
10	2.21	2.55	2.55	3.45	4.25	3.00	3.95	4.30	2.65	3.75
11	1.17	1.80	.95	1.60	1.85	1.00	1.65	1.85	.95	1.55
12	1.47	1.40	1.40	1.80	2.30	1.30	2.25	2.70	1.10	2.00
13	—	4.20	3.05	4.10	4.65	3.15	4.25	4.20	2.80	3.70
14	1.77	3.00	2.25	3.20	3.75	2.30	3.85	3.85	2.15	3.25
15	—	2.20	1.65	2.50	2.45	1.70	2.35	2.45	1.50	2.25
16	1.79	2.00	2.00	2.40	2.75	1.85	2.55	2.60	1.70	2.60
Average		2.35	1.90	2.65	3.10	1.90	2.85	3.13	1.75	2.70

on May 7 for the 4:00 to 8:00 p.m. exposure were somewhat lower than the losses for the same period on the following days. This may be accounted for by the fact that the first weighings were taken before the plants were adjusted to the new conditions. It takes normally several hours for the root temperature to reach the desired level. By excluding these first readings a remarkable uniformity in water loss can be noticed for each photoperiod from day to day between May 8 and May 10 inclusive. The degree of variability was calculated by averaging the transpiration values on these 3 days for each light period separately, and figuring out the percentage deviation from the average. As a result of these calculations it was found that none of the determinations deviated more than 15 per cent from the mean. As a matter of fact in 91 per cent of the readings the percentage deviation from the average was less than 10, and in 60 per cent of the cases, less than 5. This is characteristic for the normal daily variability in water loss under controlled conditions, as calculated previously (1) from a large number of transpiration determinations. In contrast to this low variability when each light period is considered separately, the deviations in water loss during 12:00 to 4:00 a.m. from that during the 8:00 to 12:00 a.m. and 4:00 to 8:00 p.m., periods, respectively, are much higher. In 74 out of a total of 80 cases, there was an increase of 30 per cent or more in water loss for the last two periods over the loss for 12:00 to 4:00 a.m. and in 45 cases this increase was more than 50 per cent. There were only six cases with an increase of 20 to 30 per cent, and none below 20 per cent.

This pronounced drop in transpiration during the 12:00 to 4:00 a.m. period, despite perfect constancy of all environmental conditions, is shown, also, in Fig. 1, in which averages only are indicated and the period of experimentation is extended. On May 10 a new light cycle was introduced consisting of the following photoperiods: 8:00 to 12:00 p.m., 4:00 to 8:00 a.m., and 12:00 to 4:00 p.m. On May 16 a change

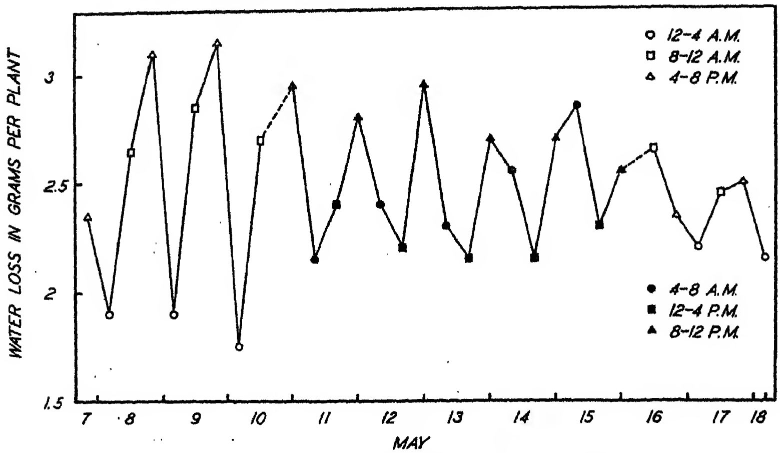

FIG. 1. Periodicity in transpiration of Eureka lemon cuttings during 4-hour light periods (dotted lines indicate change of light cycle).

to the original cycle followed. The introduction of a new cycle is indicated in the figure by dotted lines. There was an 8 hour exposure of darkness between each change of the light cycle. Transpiration determinations were made for the period of darkness as well as for the period of illumination. However, they are not reported here because of low transpiration one cannot be too certain about the significance of the differences. The values were only 10 to 12 per cent of those in light and did not seem to exhibit any periodicity. After the change in cycle on May 10 the diurnal fluctuations appeared to fade out gradually. They should not be considered therefore as constant, but rather typical of the first few days of experimentation. Additional evidence for this contention is submitted in the next section.

PERIODIC TRANSPIRATION AS RELATED TO THE LIGHT HISTORY OF THE PLANTS

In order to check whether the light condition prior to investigation was responsible for the above observed results the first 10 plants were

TABLE II—TRANSPIRATION LOSSES IN GRAMS PER PLANT FOR 12-HOUR LIGHT PERIODS (8:00 P.M. TO 8:00 A.M.)

Plant No.	May						
	22	23	24	25	26	27	28
1	7.75	7.30	7.15	7.55	7.55	6.75	7.30
2	4.90	5.05	5.00	5.35	4.95	5.15	5.20
3	7.05	6.95	6.75	7.25	6.40	6.20	6.00
4	6.55	6.45	6.00	6.60	5.90	5.60	5.50
5	7.60	7.60	6.80	7.10	6.50	6.20	6.30
6	9.10	9.30	9.20	9.70	9.30	9.20	9.20
7	9.10	8.80	8.40	8.70	8.00	7.80	8.00
8	8.75	8.65	8.20	8.55	7.75	7.20	7.20
9	13.65	13.35	12.65	14.25	13.95	14.15	14.55
10	16.45	14.75	13.40	15.80	14.50	14.10	13.60
Average	9.10	8.80	8.35	9.10	8.50	8.25	8.30

subjected to an inverted day and night, that is to a light exposure from 8:00 p.m. to 8:00 a.m. alternating with a period of darkness from 8:00 a.m. to 8:00 p.m. Weighings were taken immediately before and after turning the lights off, and are reported in Table II.

It can be seen from Table II that the losses were uniform from day to day. The readings for each plant for the 7 days were averaged and the deviations from the average calculated. It was found that in 93 per cent of all cases the percentage deviation from the mean was less than 10, and in 57 per cent less than 5. The night losses, that is the losses during 8:00 a.m. and 8:00 p.m. in darkness were also uniform and amounted to about 10 to 15 per cent of the daily water lösses. From past experience it can be concluded that this set of plants was physiologically active and capable of rapid response to changes in the environment.

On May 29 these plants were subjected to the 4-hour cycle again, as they had been on May 7. The only difference was the fact that now their previous history was not natural daylight but a 12-hour artificial light period during the night between 8:00 p.m. and 8:00 a.m. Along with these 10 plants, from now on referred to as series A, six cuttings were brought from the greenhouse, numbered 11a to 16a inclusive and designated as series B. These six plants were taken from the same trees and planted at the same time as the remainder, the only difference being that they were subjected to normal daylight for three more weeks than series A. As far as the light history is concerned the series B plants were on May 29 in essentially the same physiological condition as plants 1 to 10 of series A were on May 8. In Table III a summary of the data is given for the two series for the first 3 days and in Fig. 2 the results are compared on the leaf surface basis.

During the 12 to 4 a.m. period the water loss for plants on series A was at a maximum while those in series B showed a minimum. The other two photoperiods occurred during the time of the day which corresponded to the dark exposure for series A before May 29. Apparently this brought about a low transpiration rate during 8 to 12 a.m. and 4 to 8 p.m. in the latter, while for plants in series B the water loss was considerably higher than for the 12 to 4 a.m. period. This behavior obtains for each of the individual plants as well as for the average. Comparing the water loss during the 12 to 4 a.m. photoperiod on May 29 with that on May 8 one finds an increase of about 80 per cent for plants of series A. This increase is doubtlessly due to

TABLE III—Average Water Loss in Grams per Plant as Related to Light Conditions Before Experimentation

Plant Series	May 30			May 31			June 1		
	12 to 4 A.M.	8 to 12 A.M.	4 to 8 P.M.	12 to 4 A.M.	8 to 12 A.M.	4 to 8 P.M.	12 to 4 A.M.	8 to 12 A.M.	4 to 8 P.M.
A*	3.35	2.35	2.45	3.20	2.40	2.50	2.95	2.60	2.25
B	2.20	3.40	2.60	2.00	3.30	3.45	2.30	3.15	3.00

*A—subjected to artificial light from May 22 to May 29 for 12 hours daily from 8:00 p.m. to 8:00 a.m.
B—greenhouse plants grown under normal daylight until May 29.

day and night inversion before the test. Unfortunately no comparison of this nature can be made for series B because no controlled conditions were available in the greenhouse with sunlight as the source of illumination.

It should be emphasized that the inversion in periodicity in plants of series A was brought about by exposure to only nine days of an inverted day. Apparently this treatment was sufficient to change a condition brought about by approximately ten months of growth under natural day and night, since the cuttings removed from the trees on November 1, 1938 were of the July 1938 cycle of growth. The physiological habit established by the plant is, therefore, altered readily. However, the response is not rapid enough to be explained by our present knowledge of the effects of environmental factors on transpiration or on stomatal movement.

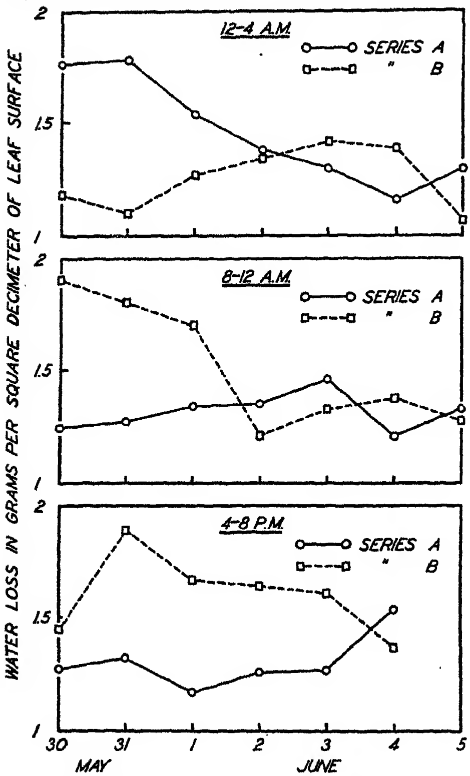

Fig. 2. Transpiration of Eureka lemon cuttings in relation to past light history. Series A subjected to 12 hours of light from 8 p.m. to 8 a.m., May 22 to May 29. Series B, greenhouse plants grown under daylight until May 29.

Conclusions

When plants grown for several months under natural light are subsequently subjected to artificial light periods of 4-hour duration alternating with 4 hours of darkness the minimum water loss takes place between 12:00 and 4:00 a.m. Maximum transpiration values for this period can be obtained after a preliminary exposure to an inverted artificial day from 8:00 p.m. to 8:00 a.m. The observed periodicity is pronounced during the first 3 or 4 days following change of conditions and appears to diminish with time.

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The Influence of Soil Temperature on the Rate of Transpiration of Young Orange Trees

By S. H. CAMERON, *University of California, Los Angeles, Calif.*

DURING periods of low temperature orange trees frequently wilt severely. Usually the wilt is of short duration — a few hours to 2 or 3 days — and does not involve an appreciable loss of foliage or fruit. There is no uniformity of opinion regarding the factors responsible for this wilt. Some investigators believe it to be due to low root temperatures which reduce the rate of intake of water while others consider that it is caused by an abnormally high rate of transpiration associated with very low atmospheric humidity. Usually during at least portions of these periods of low temperature the dew point is below the minimum temperature, indicating a very dry atmosphere. Since often low soil temperature and low relative humidity obtain simultaneously it would seem that wilting might be due to both conditions.

During the freeze of January 1937 orange trees at Riverside remained wilted for approximately 3 days. Huberty and Compton (3) obtained records of soil and air temperatures and determined the relative saturation deficit (2) of typical wilted leaves. At the 16 and 22 inch levels the soil temperature was approximately 40 degrees F. No record was obtained at lower depths; however it probably was below 50 degrees F throughout most of the root zone. The minimum air temperature was 18 to 20 degrees F. Mr. Floyd D. Young, Government Meteorologist, reported a dew point of —8 degrees F for Corona 12 miles distant. Under these conditions a leaf water deficit of 21 per cent was determined which is the highest value these investigators have ever obtained. Nevertheless the trees subsequently, recovered with very little apparent injury.

The availability of special equipment designed primarily for a study of the effect of soil temperature on root growth afforded an opportunity to obtain some preliminary information regarding the effect of one of these factors, namely soil temperature, on the rate of water loss of young Valencia orange trees. This equipment which is illustrated in Fig. 1 is essentially a box or lycimeter 18 x 24 x 36 inches with one glass side, which is protected by a removable light-tight cover. A welded angle iron frame provides the necessary rigidity. On one end of the box are mounted two manifold systems, a supply and return, which are connected by 20 U tubes extending to the opposite end of the box. By circulating a heated or cooled brine through this pipe system it is possible to quickly change the temperature of the soil in the box and to maintain any desired temperature indefinitely. The box is also equipped with soil heating cable connected through a thermostat. This auxiliary heating system permits maintaining soil temperatures above average atomsphere temperatures for long periods without involving the use of external brine heating and circulating equipment.

A record of soil temperatures is obtained by a recording thermometer the bulb of which is located approximately in the center of the box.

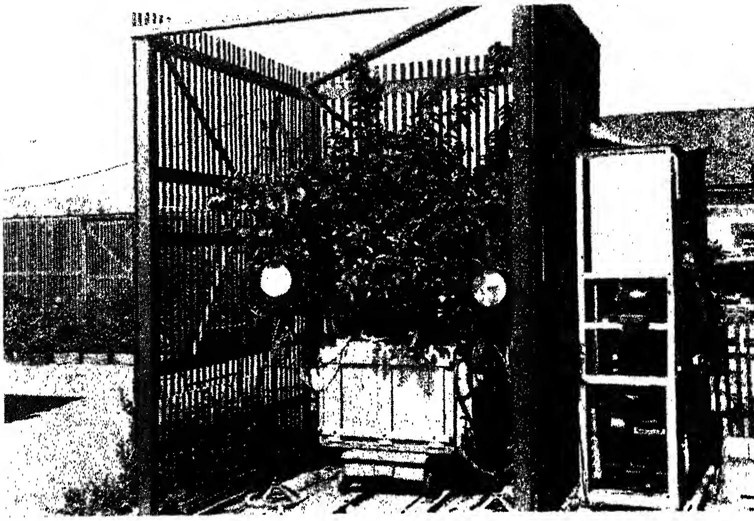

FIG. 1. Equipment used in a study of the effect of soil temperature on the rate of transpiration of young Valencia orange trees.

When brine is circulated through the box the soil temperature is maintained practically constant. With the soil heating cable the temperature fluctuates approximately ±2 degrees F.

By placing the box on a large platform scale a record of water lost through transpiration is readily obtained. While such studies are in progress the box is covered with a tight-fitting top to prevent loss by evaporation.

In 1936 two nursery grown Valencia orange trees on sweet orange rootstock were planted in the box. The trees grew well and were in healthy vigorous condition when the determinations here reported were made. The trees are of course dwarfed due to crowding and root restriction. Judging by the root concentration in front of the glass, it is believed that the roots have occupied all portions of the soil. The soil is a medium sandy loam, which holds about 10 per cent available moisture.

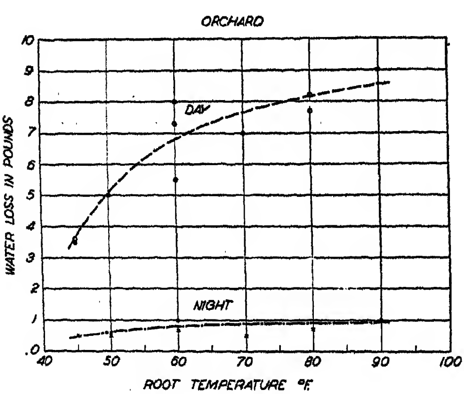

FIG. 2. Influence of soil temperature on the rate of transpiration of young Valencia orange trees under field conditions.

Several series of observations to determine the effect of soil temperature on the rate of water loss

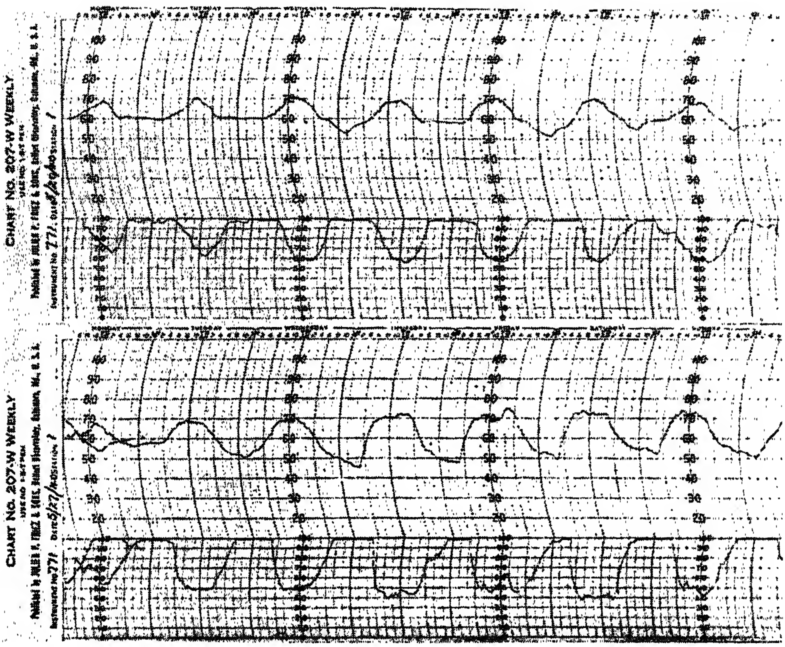

FIG. 3. Record of atmospheric temperature and humidity during the period in which the data presented in Fig. 2 was obtained.

under field conditions have been made. The results have been essentially similar for all, therefore the data obtained during only one series is presented in Fig. 2. These observations were made during the last 2 weeks of May 1940. During each series of observations records of atmospheric temperature and humidity as well as soil temperature were obtained. A record of atmospheric temperature and humidity, obtained in a standard weather bureau shelter, during the period in which the data presented in Fig. 2 were obtained is presented in Fig. 3. It will be observed that except on May 30 and 31 on which days the temperature was higher than usual, air temperature and humidity were essentially the same from day to day.

The results presented in Fig. 2 indicate a marked reduction in rate of water loss as the soil temperature is reduced from 90 to 43 degrees F. This is particularly noticeable in the daytime losses which are approximately ten times as great as the losses at night. As indicated by the several points on the graph there was considerable daily fluctuation in loss particularly at the intermediate temperatures. This is to be expected under field conditions. Under controlled conditions (Fig. 4) the fluctuations are much less marked. The record presented in Fig. 3 shows that the relative humidity approached 100 per cent every night. This probably in part accounts for the relatively small losses during this period. Later observations made during a period of unusually low

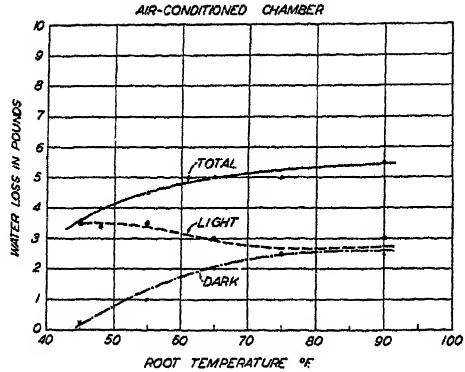

FIG. 4. Influence of soil temperature on the rate of transpiration of young Valencia orange trees in an air-conditioned chamber.

relative humidity which persisted throughout the night indicate that nighttime losses under such conditions are very much greater. That light probably also plays a part is indicated by the results of Bialoglowski (1) who reports a much greater rate of transpiration of rooted lemon cuttings during the light than during the dark period notwithstanding the fact that his observations were made in an air conditioned chamber in which temperature and humidity were constant.

During the period June 2 to 13, 1940, the equipment was moved into an air conditioned chamber in which the air temperature was maintained at 75 degrees F, the relative humidity 55 per cent and air movement 3,000 cfm. The lights which were a combination of Mazda and fluorescent were controlled by a time switch for alternating 12 hour periods of light and darkness which corresponded with the natural day and night periods.

Under these conditions the results as indicated in Fig. 4 were somewhat different from outdoor conditions. Total 24-hour-period losses were less than under outdoor conditions except at low root temperatures. Above approximately 70 degrees F root temperature, light and dark period losses were almost identical. Below 70 degrees F root temperature the light period losses increased relative to the dark period losses although the total losses were less than at higher temperatures. The fact that 24-hour-period losses were less in the chamber where the maintained temperature and humidity were similar to midday conditions out of doors, and should therefore have caused even greater losses suggests that some other factor was limiting transpiration. This together with the equality of light and dark period losses above 70 degrees F root temperature suggests that light may have been the limiting factor. It was not possible in the chamber to obtain a light intensely greater than approximately 300 foot candles at the periphery of the trees which compares with at least 6,000 foot candles under field conditions.

That low soil temperature reduces the rate of absorption of water by plants has long been known. Kramer (4) has recently summarized the literature in this field particularly as it relates to herbaceous plants. He concludes that decreased water absorption is due to a decrease in permeability of the root membranes combined with an increase in the viscosity of water. In the present series of investigations it was observed that the leaves showed evidence of stress when the root tem-

perature was reduced to 48 degrees F or below. Definite signs of wilting were evident at temperatures below 45 degrees F.

In order to obtain some measure of the stress under which the leaves were placed due to a decrease in soil temperature, determinations of the relative saturation deficit were made using the technique employed by Halma (2). The results are presented in Table I. They indicate an appreciably higher leaf water deficit at low than at high soil temperatures both in the field and in the air conditioned chamber.

TABLE I—Effect of Soil Temperature on the Relative Saturation Deficit of Valencia Orange Leaves

Location	Soil Temperature (Degrees F)		
	85	45	40
Orchard	2.44	5.38	....
Air conditioned chamber	3.01	5.29	6.82

Summary and Conclusions

Observations on the effect of soil temperature on the rate of water loss of young Valencia orange trees suggest the following conclusions: That decreasing soil temperature from 90 to 45 degrees F results in a marked decrease in the rate of water loss; and that under usual environmental conditions transpiration during the day may be ten times as great as at night.

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Certain Factors Influencing the Size of Dried Prunes

By A. H. Hendrickson and F. J. Veihmeyer, *University of California, Davis, Calif.*

THE size of dried prunes is a factor of primary importance in the marketing of this product, the small sizes selling for a lower price than the large ones. The proportions of the various sizes of prunes produced during the past 8 years by the French prune trees in the experiments dealing with the water relations of fruit trees at Davis, California, have shown some interesting results related to the effect of the numbers of prunes produced and to the irrigation treatment. The experiments were conducted with bearing trees planted in 1923, 24 feet apart on the square system in a Yolo loam soil. The orchard was laid out to include 18 plots, 11 of which were irrigated while the remaining 7 received no water during the growing season. A previous publication (1) describes the treatments in detail. In this report all trees receiving water during the growing season are placed in one group, and those left dry, in the second. Some of the so-called irrigated plots received treatments that were intermediate between those kept moist continuously and those left unirrigated. In a few instances several of these intermediate plots were inadvertently allowed to become dry before the fruit reached full size, and this soil moisture condition undoubtedly affected the size of the fruit to some extent, but not as decisively as in the unirrigated plots. All the experimental plots were surrounded by suitable guards. The crops on the experimental trees were not thinned.

After the fruit was dehydrated, it was run over a sizer that separated it into seven sizes. For the purpose of this study the fruit that dropped through the first two screens was placed in the first class, that from the third and fourth screens, in the second, and that from the fifth and sixth screens and from the end of the grader in the third. The fruits segregated in the first class were 81 to the pound or smaller, those in the second, 50 to 80 to the pound, and those in the third, larger than 50 to the pound. For convenience, these sizes are referred to in this report as small, medium and large.

The *percentages* of these sizes varied from year to year, but the proportions of medium sized fruit showed less variation than those from the other two sizes. The proportions of the small and the large sizes did not show any close relationship with the amount of crop produced, although the dry plots consistently produced a larger proportion of small sizes than the irrigated plots. During 8 years the average *percentage* of medium sizes in the irrigated plots was 38.6 and in the dry plots 38.7. These data seemed to indicate that the weight of the crop produced had but comparatively little effect on the percentage of medium sized fruit, and that, furthermore, the average percentage of medium sized fruit was not markedly influenced by the irrigation treatment. The chief exception occurred in 1933, the first year of differential irrigation treatment. The combination of a large crop and

TABLE I—PERCENTAGES BY WEIGHT OF SMALL, MEDIUM AND LARGE PRUNES AND AVERAGE YIELDS (TONS PER ACRE)

	1933	1934	1935	1936	1937	1938	1939	1940
			Irrigated Plots					
Small sizes	45.9	26.9	27.9	15.5	36.9	17.1	17.5	11.1
Medium sizes	34.4	45.2	45.6	38.1	43.0	30.7	42.5	29.6
Large sizes	19.8	27.9	26.5	46.4	20.0	52.1	40.0	59.3
Average yields	9.8	2.7	4.8	4.0	13.6	9.7	13.2	11.9
			Dry Plots					
Small sizes	83.6	45.8	53.1	28.1	48.2	19.7	22.2	25.4
Medium sizes	13.6	42.8	36.6	44.7	44.3	37.8	47.9	41.9
Large sizes	2.7	13.6	10.2	27.2	7.4	42.5	29.3	32.6
Average yields	6.5	2.7	2.2	2.7	10.6	7.6	8.4	8.1

the exceptionally late season may account for the large percentage of small sizes and the small proportion of medium prunes produced. The average percentages of fruit of the different sizes are given in Table I.

A study was then made to ascertain, if possible, the other factors affecting the sizes of fruit produced. Lilleland and Brown (2) have shown that the size of apricots is correlated with the number of fruits on the tree. In our experiment, the numbers of prunes per plot from the irrigated treatments were first plotted against the weights of the fruit from the last five size grades, or those which were 80 to the pound or larger. The curves obtained showed agreement with portions of the curve for apricots obtained by Lilleland and Brown (2), depending on the season and the numbers of fruits borne. Having established that the weights of desirable sizes of prunes were related to the numbers borne in the same general way that the weights of marketable apricots are related to the numbers of that fruit, further study was made on the size-number relationship. The number of prunes per plot of eight trees was then plotted against the weights of dried fruits in the three sizes previously described. Records were kept on a plot basis because of the chances for error in weighing, dipping, drying and grading the crops from individual trees. From the curves assembled it was apparent that two factors, number of prunes per plot and lack of readily available soil moisture during the growing season, singly or in combination, influenced the weights of prunes produced.

The results for 1939 are shown in Fig. 1, while the formulae for the curves for the other years are given in Table II.

The relationships illustrated in Fig. I show that the weights of small prunes in the irrigated plots increased with the numbers of fruits on the trees. In a similar way the weights of small fruits, from the dry plots, in which the available soil moisture was exhausted early in July, increased with the numbers of prunes on the trees. The position of the broken line with reference to the solid one indicates the difference in yields of small fruit that may be attributed to lack of available moisture after early July. Thus, the weights of small fruit in the irrigated plots were related to the numbers of fruits borne while the weights of small fruit in dry plots were related to both the number produced and the irrigation treatment.

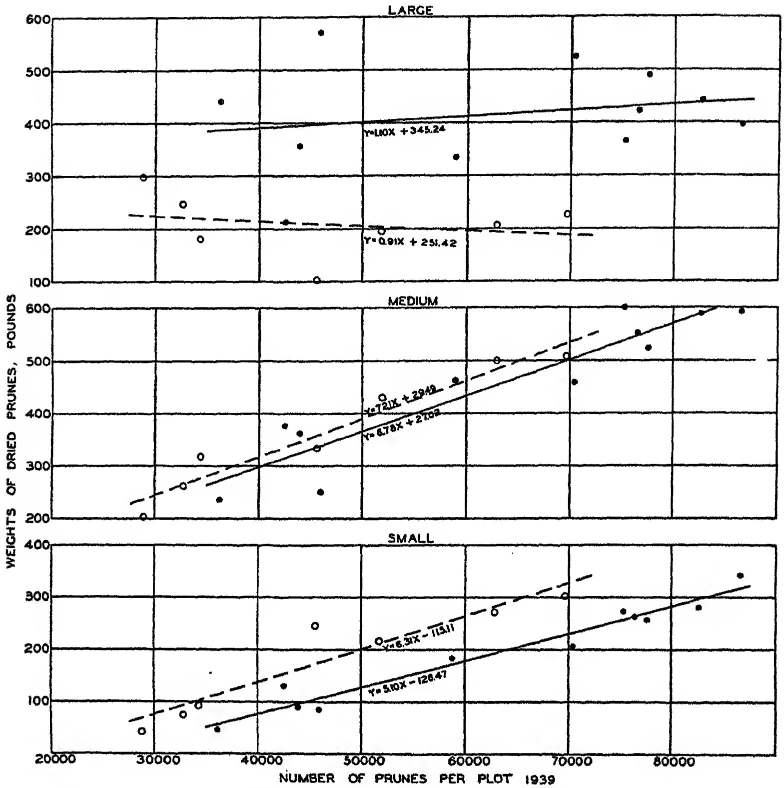

FIG. 1. Relationship between weights of small, medium, and large dried prunes, and numbers of fruits, 1939. Y = weights of dried prunes, and X = numbers of fruits.

In the medium sized group the lines showing the dried weight-number of fruits relationship are nearly parallel and fairly close together. Apparently, the weights of medium sized fruit in both treatments were related only to the number of fruits borne.

In the large sized group both lines were nearly horizontal, indicating but little relationship between the numbers produced and the weights of this size fruit. The position of the broken line, however, shows a marked effect brought about by the lack of available soil moisture after the first part of July. Apparently, the maximum weight of large sized prunes that could be produced during the 1939 season in the irrigated plots was roughly 400 pounds, while that of the dry plots was 200 pounds. The irrigated plots that had 75,000 or more fruits were only able to produce as many pounds of large fruits as those that bore about half that number. In a similar manner the dry plots produced about 200 pounds of large sized fruit whether there were 30,000 fruits on the trees or 70,000.

TABLE II—RANGES OF NUMBERS OF FRUITS BORNE, AND RELATIONSHIP BETWEEN WEIGHTS OF SIZES OF DRIED PRUNES AND NUMBER OF FRUITS BORNE (x)

		Small		Medium		Large	
Year	Number of Fruits	Irrigated Plots	Unirrigated Plots	Irrigated Plots	Unirrigated Plots	Irrigated Plots	Unirrigated Plots
1933	33,000 to 85,000	8.07 X − 153.86	3.72 X − 247.17	2.46 X − 129.54	−1.23 X + 165.68	−1.85 X + 287.56	−1.52 X + 126.93
1934	10,000 to 41,000	7.03 X − 61.27	6.35 X − 9.38	5.35 X + 32.36	3.57 X + 47.20	−0.55 X + 99.73	0.96 X + 12.45
1935	6,000 to 36,000	5.27 X − 20.59	9.51 X − 31.26	7.74 X − 11.83	0.40 X + 59.52	2.66 X + 38.53	−0.83 X + 29.15
1936	5,000 to 50,000	5.06 X − 41.42	10.08 X − 103.35	8.28 X − 22.66	0.36 X + 125.45	0.90 X + 137.63	−1.21 X + 104.91
1937	34,000 to 96,000	8.44 X − 207.31	9.32 X − 192.23	2.64 X + 229.75	0.34 X + 337.92	1.94 X + 54.36	0.02 X + 59.16
1938	20,000 to 59,000	6.85 X − 142.48	7.41 X − 117.19	7.94 X − 87.05	8.59 X − 59.19	−3.92 X + 531.76	−4.08 X + 335.49
1939	29,000 to 86,000	5.10 X − 126.47	6.31 X − 115.11	6.78 X + 27.02	7.21 X + 29.49	1.10 X + 345.24	−0.91 X + 251.42
1940	33,000 to 58,000	6.47 X − 209.96	11.31 X − 304.14	8.92 X − 162.80	1.75 X + 194.91	−5.96 X + 808.12	−9.86 X + 608.19

It will be noted that one of the irrigated plots deviated widely from the remainder of the large sized group. The soil-moisture record of this plot shows that the soil moisture was reduced to the permanent wilting percentage about the middle of July and remained there for more than a week before the moisture supply could be replenished.

The straight lines fitted to the data for the other seven years, with certain exceptions, show definite relationships. In the irrigated plots there was a marked and fairly consistent relationship between numbers of fruits borne and weights of small sized fruit. The differences in the slopes of these curves from year to year, as indicated in Table II, were not pronounced. The same general type of relationship was also found in the dry plots, when the weight of small dried fruit likewise increased with the number of fruits borne. During the first year of differential treatment, the slope of the curve for the dry plots was not as great as it was during the other years. The curves for the small sizes in the dry plots lie above those of the irrigated in every case, indicating the effect of the lack of readily available soil moisture.

The curves for the medium sized fruit in the wet plots show distinct relationship with the numbers of prunes produced. The slopes are not so great in 1933 and in 1937 as they are in the other years. The results during these 2 years may have been affected by the fact that 1933 was the first year of differential irrigation treatment while in 1937 the total number of prunes per plot was greater than during any other year of the experiment.

In the dry plots the weights of medium sized fruit did not show consistent relationships with either the numbers borne or the irrigation treatment. The x factors which represent the slopes of these curves in Table II indicate a distinct relationship between weights of medium sized fruit in the dry plots and numbers borne during 3 years, but in the remaining 5, no such relationship occurred.

The curves for the large sizes in the wet plots were nearly horizontal in 4 years, sloped distinctly downward in 3 years and slightly upward in 1 year. The horizontal curves indicate that the trees produced the maximum weight of large sized prunes which was not closely related to the numbers of prunes on the trees. In each of the 3 years that the slope was downward it was due to the fact that certain plots were lower than the others in their yield of large sizes probably because of soil moisture conditions. The plan of the experiment is to allow some of the plots to reduce the soil moisture to the permanent wilting percentage, before replenishing the supply. Other plots are irrigated when the soil moisture is about 3 per cent above the permanent wilting percentage. In order to secure contrast between these two groups, the former, in a few cases, were not irrigated until the last moment. Then, because of the acreage involved, several days were required to apply the water with the result that sometimes these plots were reduced to the permanent wilting percentage and some of them apparently remained at this moisture content long enough to affect the size of the fruit. The short delays in applying the water seemed to affect the large sizes more than either the small or medium. The upward slope in 1935 may have been due to the exceptionally light crop of that year.

The curves for the large sizes in the dry plots were horizontal or nearly so in 6 of the 8 years of the experiment, and downward in 2. In all cases they were below those of the wet plots, indicating the effect of lack of moisture on the weights of large sized fruits produced.

Summary

During an 8 year trial, French prune trees at Davis, California, produced approximately equal *percentages* of medium sized dried prunes whether they were irrigated or not. On the average, 38.6 per cent of the crop from the irrigated plots, and 38.7 per cent from the dry plots were of medium size.

The weights of small sized prunes increased with the numbers of prunes borne in both the irrigated and the dry plots. The weights of small sizes in the dry plots were further increased by the lack of readily available soil moisture during the growing season.

The weights of small prunes in the wet plots were affected by the numbers of fruits on the trees, while in the dry plots the weights of small fruits were affected by both numbers borne and by irrigation treatment.

The weights of medium sized prunes in the irrigated plots also increased with the numbers of fruits on the trees.

In the dry plots the weights of medium sized fruit showed fairly close relationship to the numbers on the trees during 3 years, but not during the other 5.

The weights of large sized prunes in the wet plots did not show a close or consistent relationship with the numbers of fruits borne. Apparently, in some seasons there is little or no increase in weight of large size fruit with an increase in numbers, and in some years there is a decrease in weight with an increase in numbers.

In a similar way the trees in the dry plots produced less fruit of large size than the irrigated trees, and the weights produced were not closely related to the numbers of fruits borne.

With prune trees that did not suffer for water during the growing season, the weights of the various sizes of dried fruit were largely determined by the amount of crop set. With unirrigated trees the weights of the various sizes were determined by the numbers of fruit on the tree and by the irrigation treatment.

Lack of available moisture during the growing season increased the weights of the small or undesirable sizes, decreased the weights of large sizes but did not markedly influence the weights of the medium sizes.

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Apple Blossom Removal With Caustic Sprays

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IN THE 1939 Proceedings, data were reported (1) indicating that Elgetol in concentrations of .1 to .2 per cent applied to apple blossoms on bagged unit-branches was effective in preventing the set of Rhode Island Greening without serious damage to the foliage. Investigations herein reported were carried on to determine the effect of this material and also of Reico (a tar oil), applied to blossoming trees of different varieties under orchard conditions. In these experiments the trees were sprayed thoroughly from the ground with a "Friend" single nozzle gun under 450 to 500 pounds pressure.

Table I gives the results obtained with the variety Wealthy. The trees were mature, growing in sod with plenty of space and pruned out rather thin. The growth showed evidence of nitrogen deficiency. The trees were blossoming fully with about 95 per cent of the spurs bearing flowers. On May 27, the date of the first spraying, about two-thirds of the blossoms were open and on May 29 at the time of the second spraying, practically all of the blossoms were open with some petals falling (Table I).

TABLE I—The Effect of Elgetol Applied During Bloom on the Set of Apple Fruit (Wealthy, Spring 1940, Counts Based on Unit Branches)

Treatment	Number Blossoming Spurs	Blossoming Spurs With Fruit (Per Cent)	Number Fruits per 100 Blossoming Spurs	Injury
Check	144	18.1	21	———
Check	93	29.0	32	———
.1 per cent, May 27 and 29	111	2.7	3	Medium
Check	149	45.0	58	———
.1 per cent, May 27 and 29	116	6.0	6	Slight
Check	152	28.9	31	———
.2 per cent, May 27 and 29	59	0	0	Severe (weak tree)
.2 per cent, May 27 and 29	129	0	0	Medium
.2 per cent, May 27	69	0	0	Medium
Check	76	26.3	29	———
Check	136	33.1	37	———
.2 per cent, May 27	83	0	0	Medium
.1 per cent, May 27	104	8.6	9	Medium
Check	107	57.0	72	———
Check	115	60.9	81	———
.1 per cent, May 27	188	20.7	22	Slight

Probably the best expression of the effectiveness of the different treatments in preventing set is the number of fruits set per 100 blossoming spurs. Expressed in this way, 20 to 25 fruits per 100 blossoming spurs would be considered a commercial crop. Averaging the different treatments in Table I gives for the checks, 45 fruits per 100 blossoming spurs; .1 per cent Elgetol applied once, 15 fruits; .1 per cent applied twice, 4.5 fruits; .2 per cent applied once, 0 fruits; .2 per cent applied twice, 0 fruits. Counts were based on unit branches selected at the time of blossoming as being representative of the whole tree.

In referring to the amount of injury the term "slight" means that leaves were somewhat crinkled at the edges with occasional brown spots near the edges but that no spurs were killed. "Medium" injury indicates a condition where many leaves were noticeably browned on the edges and a few spurs were dead. In "severe" injury all the leaves were burned on the margins and about one-fifth of the spurs dead.

In another orchard in a high state of vigor, five Wealthy trees were sprayed with .1 per cent Elgetol. Only about one half of the blossoms were out, with some of the buds on the terminals and laterals very tightly closed. Five checks averaged 94 fruits per 100 spurs. The five treated trees averaged 69 fruits. It is obvious that the set was very high on both. Failure to inhibit the set was apparently related to the closed blossoms at the time of spraying which were not seriously injured. The higher set on the checks as compared with the orchard reported in Table I is probably due to the greater vigor of the trees.

The results with variety Wolf River are reported in Table II. The

TABLE II—THE EFFECT OF ELGETOL APPLIED DURING BLOOM ON THE SET OF APPLE FRUITS (WOLF RIVER, SPRING 1940, COUNTS ON UNIT BRANCHES)

Treatment	Number Blossoming Spurs	Blossoming Spurs With Fruit (Per Cent)	Number of Fruits per 100 Blossoming Spurs	Injury
.1 per cent	43	18.6	19	None
Check	47	46.8	68	——
.1 per cent	47	3.9	5	Slight
.1 per cent	65	4.6	4.6	Slight
.2 per cent	43	7.0	7	——
Check	44	52.3	61	——
.2 per cent	54	7.3	7	Slight
Check	118	22.0	25	——
.2 per cent	92	1.1	1	Slight
Check	74	21.6	24	——
Check	81	45.6	51	——

orchard was in sod and the trees in fair condition, possibly somewhat lacking in nitrogen. The trees were in full bloom at the time of application.

In this orchard the five check trees averaged 46 fruits per 100 blossoming spurs. Three trees sprayed with .1 per cent Elgetol averaged 9.6 fruits and the three trees sprayed with .2 per cent Elgetol, five fruits per 100 blossoming spurs. The injury to foliage in this orchard was very slight.

Three Oldenburg trees in a well-cared-for western New York orchard were sprayed with .1 per cent Elgetol. The blossoming was very heavy with about nine-tenths of the flowers open. The average of three checks was 43 fruits per 100 spurs. The average for the treated trees was 24 fruits per 100 spurs, or about a commercial crop. Distribution of the fruits, however, was somewhat uneven so that some thinning would have been necessary to break clusters. Clusters with several of fruits set were apparently those which were not open at the time of spraying.

In the Pomology Department orchard at Ithaca, 30 year Oldenburg trees were sprayed with Elgetol at different strengths with the following results: Eight check branches averaged 23.1 fruits per 100 blos-

soming spurs. Two trees sprayed once on May 22 with .1 per cent Elgetol averaged 19.6 fruits; two trees sprayed twice, May 22 and May 24th with .1 per cent, gave 8.3 fruit and two trees sprayed once on May 23 with .2 per cent gave 11.2 fruits per 100 spurs. Injury to the foliage of trees sprayed twice with .1 per cent solution was medium to severe with considerable spur killing. Injury from one application of .2 per cent solution was slight to medium. The relatively heavy set of fruit on the trees sprayed only once with .1 per cent Elgetol is undoubtedly related to the amount of unopened bloom. One tree sprayed with Reico lost all its leaves but held a few fruits.

In an uncared for orchard in western New York, 30 trees of several different varieties were sprayed with Elgetol at .1, .2, and .3 per cent concentration and with Reico at manufacturer's directions (1 gallon to 65 gallons water). Because of poor soil management and lack of insect and disease control in this orchard the checks did not set consistently and the data obtained were of little value. It was obvious that Reico applied at full bloom is so caustic that all foliage is burned off. Elgetol .3 per cent also produced very serious injury on three Northern Spy trees, killing most of the spurs and leaves. One tree sprayed with .3 per cent Elgetol using a broom type of gun showed less injury than those sprayed with the single nozzle gun.

The work herein reported should be considered as of a preliminary nature only and certainly gives no basis for recommendations as to the commercial use of Elgetol in controlling fruit set. Several points, however, seem fairly clear. (a) Elgetol is certainly one of the most promising materials for further experiments in bloom control. (b) The concentrations which are most promising are between .1 and .2 per cent. (c) Failure to control the set is related to the proportion of blossoms open and in the early stages of bloom. Closed blossoms are not killed by the spray, nor are blossoms that have been pollinated for a sufficiently long time to permit fertilization. (d) There is noticeably less injury to the foliage of vigorously growing trees than to trees of weaker growth. (e) Reduction in set was less with trees having ample nitrogen than with those which were nitrogen deficient.

The varieties Oldenburg and Wealthy are a special problem in that they will set under adverse conditions. They also produce blossoms from lateral and terminal buds on vegetative shoots which open several days after those on spurs. This spread of bloom makes it necessary to spray at least twice in order to control fruiting. The whole matter of spraying in bloom to remove blossoms altogether or to thin the crop requires further study especially as to its injurious effect on the leaf surface. Injury to foliage even with dilute solutions may be such that the use of Elgetol may be inadvisable in the long run.

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Effect of Branch Ringing Before and After Blossoming on the Fruit Set of the Delicious Apple[1]

By W. H. Griggs and A. Lee Schrader, *University of Maryland, College Park, Md.*

THE studies here presented were initiated in the spring of 1940 and constitute only a preliminary phase of a more extensive investigation concerning factors associated with productiveness in the Delicious apple.

Murneek (3) has recommended ringing at the time of full bloom to increase fruit set for several apple varieties including Delicious. Greene (1) has reported greater setting of Grimes on branches when ringed April 28, 1931 and May 18, 1931 as compared with branches ringed May 1 and May 4. Heinicke (2) also has reported an increased set of fruits on several apple varieties as the result of ringing branches just before the blossoms opened. This study on Delicious contemplated a more thorough investigation of the time of ringing as a factor in increasing set. A measure of the variability in trees in response to this ringing treatment was also obtained.

Forty 20-year-old Delicious trees growing on Chester clay loam soil under blue grass sod were selected for these ringing studies. Prior to 1938, the trees received nitrate of soda annually at the rate of 5 pounds per tree and a moderate amount of pruning. In 1938, the grower, feeling that the trees were excessively vigorous, discontinued fertilizer and pruning treatments, with the intention of increasing production. In spite of the fact that these trees have blossomed profusely and have made vigorous growth, they have been consistently low yielding; however, no data were available relative to the percentage set for the years prior to the beginning of these studies.

For the present study four large branches, about 3 inches in diameter at the base, were selected for ringing on each tree. One of the four branches was ringed May 3 at the pink stage, another May 16 immediately following petal fall, and still another on June 2. The fourth branch served as a check for the three ringed branches. Ringing was accomplished by means of a pruning saw of the curved type and the wounds were sealed with grafting wax. Counts were based on approximately 100 blossom clusters tagged on the outer part of each branch.

TABLE I—Effect of Branch Ringing Before and After Blossoming on the Fruit Set of 20-Years-Old Delicious Apple Trees, 1940 (Mean for 40 Trees)

Treatment	Mean Set Per 100 Clusters
Check—(no ringing)	7.73
Ringing on May 3	10.94
Ringing on May 16	13.06
Ringing on June 2	8.13

Difference required for significance at 5.0 per cent level =2.98; at 1.0 per cent level 3.86.
F value for trees =4.19**; for treatments 5.07**.
**Significant beyond the 1 per cent point.

[1]Scientific Contribution No. 535, Department of Horticulture, Maryland Agricultural Experiment Station.

Lanolin Emulsions as Carriers of Growth Substances

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IN THEIR efforts to make use of growth promoting substances, research workers have encountered difficulties in their application. A method which serves very well for applying growth promoters to small areas of plant tissue such as a stigma or other limited surface, is less satisfactory when employed in treating larger areas of stem tissues to stimulate root formation on a scale suitable for transplanting. In order to overcome such difficulties it was necessary to work out a method to facilitate application to larger plant surfaces without losing the proven merits of the methods used in small applications.

Since the methods of applying plant growth promoting substances by the writers proved advantageous to their work, these details are presented in the interest of advancing the use of growth promoting substances in solving plant problems.

The literature on plant growth substances abounds with references to lanolin as a carrier for the various substances. More recently, however, there has been a trend toward the use of talc, and other finely powdered materials as carriers for some of the same growth substances for which lanolin was formerly used. This indicated the desire on the part of various workers for a carrier which could be applied more easily and with greater uniformity. While powders appeared to have accomplished these ends, they lacked the adhesive qualities of lanolin carriers.

In studies which the writers conducted considerable areas of woody stem tissue were treated with growth promoting substances to stimulate root formation. For such treatments it was difficult to make uniform applications with lanolin as a carrier, because it resulted in an irregular spread; some portions of the treated stems being covered with a thick layer, while other areas had little or no covering. When talc was substituted for lanolin more uniform distribution was obtained, but in the mechanics of transplanting these woody materials, considerable amounts of the powder were dislodged from the treated areas.

Seeking to retain the adhesiveness of lanolin, while improving the spreading qualities of the carrier, the writers undertook to develop a suitable lanolin emulsion to serve their needs. The results have been satisfactory, and it is believed that lanolin emulsions have advantages in uniformity of application.

In preparing lanolin emulsions triethanolamine was found to be a very satisfactory emulsifying agent, both from the standpoint of ease of preparation, and in the stability of the finished emulsions. In preparing an emulsion with triethanolamine four ingredients are used, namely, the oil to be emulsified, (in this case lanolin), water, fatty acid, and triethanolamine. Stearic acid is usually a more satisfactory fatty acid, when lanolin is to be emulsified, but others such as oleic, linoleic, and so on, may be used.

Because it was desirable to vary the consistency of the emulsion after it was prepared, the "water method" of emulsification proved most satisfactory. The process was essentially as follows: The triethanolamine, stearic acid and water were heated together until the stearic acid was melted. The mixture was stirred to a creamy soap solution, and the lanolin then added. The heating was continued without stirring until the lanolin was completely melted. This mixture, held just below the boiling point of water, was then stirred vigorously until a thick creamy uniform emulsion was formed. The emulsion was then allowed to cool, in a water bath, with frequent stirring until it reached room temperature or about 75 to 80 degrees F.

A formula that will produce a smooth, nearly white, emulsion which will remain stable almost indefinitely at room temperature, requires the following: Lanolin 38 grams, stearic acid 7.5 grams, triethanolamine 2.7 grams and water 100 grams. This formula will produce an emulsion having the consistency of "theatrical cold cream". By adding more water either to the original formula or later to the finished emulsion, the emulsion can be given any desired consistency. Accurate weighing of all ingredients is desirable for maximum stability, but it is especially important to use exactly the correct amount of triethanolamine, because of the small quantity necessary in the formula.

Tap water should not be used, because the presence of any soluble acids or alkalies tend to reduce the stability of the emulsion. Distilled water will result in a uniform stable emulsion. The importance of thoroughly stirring until complete emulsification has been effected cannot be over emphasized.

It was observed that thicker emulsions were stable indefinitely, while an emulsion having the consistency of light oil showed a tendency to separate after a few weeks. It is therefore recommended that an emulsion having the consistency of theatrical cold cream be made if a large supply is being prepared. For immediate use this may be diluted with distilled water which should be added slowly with constant slow stirring to lessen the possibility of separation.

When adding the growth promoting substances to prepared emulsions, the crystals should first be dissolved in the minimum amount of a suitable solvent, and then this solution slowly added with constant stirring to the emulsion. When relatively low concentrations of growth substances are used, ethyl alcohol, 95 per cent to absolute, will be found satisfactory as a solvent. Since alcohol decreases the stability of the emulsion, only small amounts can safely be added. It was found that dioxane[1] is a better solvent of the organic acids and amides than alcohol. It also seemed to have little deleterious effect on emulsion stability. Dioxane is therefore recommended when high concentrations of growth promoters are being used. Another solvent, carbitol,[2] while not as effective as dioxane, was much more satisfactory as a solvent than ethyl alcohol, since it had no apparent effect on emulsion stability. The described emulsion has a low alkalinity, being about pH 8, and seems to have no detrimental effect on plant tissues.

[1]1,4-Dioxane.
[2]Diethylene Glycol Monoethyl Ether.

When this emulsion was thinned too much it was difficult to keep it from spreading beyond the limit of the treated tissue. When diluted with distilled water to the consistency of thick paint the writers were able to apply it with a small brush. Sizeable areas were covered, rapidly and uniformly, the emulsion remained where it was spread and subsequent handling resulted in a negligible loss of material.

The experience the writers have had with lanolin emulsion justified their recommending it in places where neither powders nor lanolin paste are entirely satisfactory as carriers of growth promoting substances.

Some Results in Controlling the Pre-Harvest Drop of McIntosh Apples (Preliminary Report)

By M. B. HOFFMAN, *Cornell University, Ithaca, N. Y.*

BECAUSE of the seriousness of the pre-harvest drop problem in the production of McIntosh apples, much interest has been shown in the recent development of spraying the trees with certain growth substances (naphthalene acetic acid and naphthalene acetamide) to control drop. Gardner, Marth, and Batjer (1) presented data to show that an application of naphthalene acetic acid would reduce the drop of McIntosh; but the period of effectiveness for this variety was only 8 or 9 days, while for some other sorts, drop was controlled for 2 or 3 weeks.

Spray tests were conducted in New York State during 1940 for the purpose of extending the control of drop for a period of time sufficient to obtain satisfactory color and maturity. The mean temperature for the State during September was 59.1 degrees F, or a daily deficiency of 2.0 degrees. This cool weather favored good color development and resulted in the minimum drop. In one three-acre orchard in the Hudson Valley, check trees dropped only 1.5 per cent of their crop, while all the sprayed trees in eight different treatments dropped less than 1 per cent.

The pre-harvest drop in some of the experimental orchards in western New York was sufficiently heavy to yield reliable data. The sprays were applied just as the drop of perfect commercial fruits was starting. Table I shows all treatments used equally effective in controlling drop for a period of 8 to 10 days. The maturity of this crop would have benefitted if picking had been delayed for several more days, in which case the stronger concentration and duplicate application may have shown to advantage. There was apparently no difference in the effectiveness of naphthalene acetic acid and naphthalene acetamide in this test where 25 trees were used in each treatment.

TABLE I—EFFECT OF NAPHTHALENE ACETAMIDE AND NAPHTHALENE ACETIC ACID SPRAYS ON THE DROPPING OF McINTOSH

Spray Applied Sep 16. Fruit Picked Sep 24, 25, and 26

Treatment	Per Cent Drop* Sep 16-Picking
0.0005 per cent Naphthalene acetamide	3.4
0.0005 per cent Naphthalene acetic acid	3.1
0.001 per cent Naphthalene acetic acid	2.9
0.001 per cent Naphthalene acetic acid plus ¼ per cent oil	2.8
0.0005 per cent Naphthalene acetic acid—duplicated September 21	2.7
Check	20.2

*Average 25 trees per treatment, 13-yr. old, 6.4 bushels total yield per tree. Maximum temperature September 16, 73 degrees F; September 21, 82 degrees F.

In a closely planted, heavily fertilized McIntosh block, check trees dropped 48 per cent of their crop from September 17 to 28. Table II shows that a duplicate application of naphthalene acetic acid effectively controlled the drop in this orchard for 11 days. It is possible that these

sprays would have prevented drop for a longer period but excellent color and maturity had developed before picking.

TABLE II—EFFECT OF A DUPLICATE APPLICATION OF NAPHTHALENE ACETIC ACID ON THE DROPPING OF McINTOSH

Treatment	Date Sprayed	Date Picked	Per Cent Drop* Sep 17 to Sep 28
0.0005 per cent 0.001 per cent	Sep 17 Sep 23	Sep 28	6.2
0.001 per cent 0.001 per cent	Sep 17 Sep 23	Sep 28	3.6
Check	——	Sep 28	48.0

*Average of 6 trees per treatment, 25-yr. old, 17.5 bushels total yield per tree. Maximum temperature September 17, 73 degrees F; September 23, 76 degrees F.

The results of a comparison of a single and a duplicate application of naphthalene acetic acid is given in Table III. On October 1, there was little difference in the final drop between trees receiving one spray and those receiving two. Abnormally cool weather prevailed on September 26 when the second spray was made, which makes it difficult to evaluate this application.

TABLE III—EFFECT OF SINGLE AND DUPLICATE APPLICATIONS OF .001 PER CENT NAPHTHALENE ACETIC ACID ON THE DROP OF McINTOSH

Date Sprayed	Date Picked	Per Cent Drop Sep 18 to Sep 25	Per Cent Drop* Sep 18 to Oct 1
Sep 18 and Sep 26	Oct 1	2.1	5.4
Sep 18	Oct 1	2.1	9.1
Check	Oct 1	19.5	43.5

*Average eight trees per treatment, 18-year old, 19.5 bushels total yield per tree. Maximum temperature Aug 18, 76 degrees F; Sep 26, 59 degrees F.

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Spraying for Control of Pre-Harvest Drop of Apples in New Mexico

By J. V. Enzie and G. W. Schneider, *New Mexico State College, State College, N. M.*

EVIDENCE of the value of hormone sprays as a means of controlling the pre-harvest drop of apples is being reported from many sections of the country. Some of the evidence supports the findings of Gardner, Marth, and Batjer (2) of the United States Department of Agriculture, that both naphthaleneacetamide and naphthalene acetic acid are effective in preventing or at least delaying the pre-harvest drop. Murneek (4) reports definite response as a result of spraying the Delicious and Winesap varieties with these two substances. However, McCown and Burkholder (3) report that under the conditions of their experiments at Lafayette, Indiana, in 1939, a .0001 per cent concentration of a-naphthalene acetic acid was of doubtful value when applied to certain fall and winter varieties.

New Mexico has a serious drop problem and since growing conditions are somewhat different from those of other areas previously reported, it was felt that investigations of this nature would be of value. The drop of apples in the southern irrigated valleys of New Mexico is not confined to a pre-harvest period, but rather to a period which extends from the "June drop" until harvest. However, the drop is heaviest just prior to harvest. Furthermore, the drop is not confined to certain varieties, for all of them now being grown in the experimental orchard show this tendency. The problem is further complicated by rather heavy infestations of the codling moth, which accentuate the drop. Under Mesilla Valley conditions, there are four complete generations, with a distinct break between the first and second broods, after which emergence is continuous throughout the season (1). With these conditions in mind, a series of experiments to determine the effectiveness of the aforementioned hormone sprays in controlling this drop was initiated in 1940.

Materials and Methods

For these experiments, twelve 14-year-old Stayman Winesap apple trees located in the college orchard were selected. The orchard is situated in the Mesilla Valley, in southern New Mexico, at an altitude of about 3,900 feet. The trees were growing in a Gila fine sandy loam soil, having a pH of about 8.0. All trees in the experiment were subjected to similar production practices of irrigation, spraying, etc. These were divided into four groups of three each, and, insofar as possible, the groupings were based upon size of tree, size of crop, and previous drop that season. Each group included a check tree and two treated trees, thus making four replications of each treatment.

Growth Substances and Application:—Naphthaleneacetamide and naphthalene acetic acid, each at the approximate strength of .001 per cent, were employed in these experiments. Weighed amounts of the above substances were first dissolved in 400 cubic centimeters of ethyl

alcohol and then added to water in a clean spray tank. No supplementary materials were added. The treated trees were thoroughly covered by using, on each tree, approximately 25 gallons of the spray, applied at a pressure of about 250 pounds. Two applications were made to each of the treated trees. The first was applied on August 26, approximately 5 weeks before normal harvest, and the second on September 10.

Climatic Conditions:—During the course of the experiment the total rainfall was 1.28 inches. This was distributed as follows: September 6, .11; September 18, .16; September 20, .83; September 23, .03; and September 29, .15 inches, respectively. This was in addition to standard irrigation practices.

Temperatures were recorded by means of a thermograph set up in the orchard. For convenience in presenting these data, the course of the experiment may be divided into two periods corresponding with the two spray applications which were made. Period I extends from August 26 to September 10, and Period II from September 11 to September 30. The mean maximum temperatures for these periods were 91 and 85 respectively, and the mean minimums were 60 and 58. During the course of the experiment there were 10 days in the first period and five in the second on which the temperature reached 92 or above, and on two occasions in the first period it reached 97 degrees F. These temperatures are rather typical for the Mesilla Valley for the period covered.

Wind velocity was recorded by an official weather station located about one mile east of the orchard. On two occasions rather strong winds prevailed. On September 5 a maximum velocity of 26 miles per hour was reached, and on September 11 it reached 28 miles per hour.

Drop Records:—The drops were collected at 3- or 4-day intervals, beginning 1 week prior to the application of the initial spray. All apples which fell on or before August 28 (two days after the first spray application) were discarded and were not included in the calculations. The drop apples were segregated into two groups, wormy and sound, and then counted and weighed. All calculations of percentage drop were based on the total number of apples on the tree as determined by actual count. The fruit was harvested on September 30. The data were analyzed by the variance method of Snedecor (5). The authors appreciate the deficiencies of the method of analyzing this type of data, however field observations support the results of the analysis.

Results

Sound Fruit:—The results of these tests, based on sound fruit only, are presented in Table I. It will be observed that although there was considerable drop from all trees in the experiment, it was much less from the trees that were treated. The large variation within the treatments shown in Table I (also Table IV) may be explained by the fact that the trees grouped in replication 2 were larger and more vigorous at the time of this experiment. The data in Table I were subjected to an analysis of variance and the experiment as a whole was found to be

highly reliable (odds, 100:1). The least significant difference between the means of the treatments (odds, 20:1) was 8.4. Thus it appears that naphthalene acetic acid was significantly better than naphthalene-acetamide, and, also, that both materials were significantly better than the check.

TABLE I—EFFECTS OF NAPHTHALENE ACETIC ACID AND NAPHTHALENE-ACETAMIDE ON ABSCISSION OF SOUND STAYMAN WINESAP FRUITS

Replication	Total Per Cent of Crop That Dropped August 28 to September 30		
	Naphthalene Acetic Acid .001 Per Cent	Naphthaleneacetamide .001 Per Cent	Check
1	37.7	39.9	63.5
2	21.7	29.7	48.3
3	42.1	49.8	59.5
4	29.2	47.7	65.8
Average	32.7	41.8	59.3

Concerning the duration of the effectiveness of these sprays, Gardner *et al.* (2), report that naphthalene acetic acid and naphthaleneacetamide reached their peak of effectiveness about 5 or 6 days after application and continued for a period of 2 to 3 weeks. They state further that the period of effectiveness would vary somewhat, depending upon the concentration, the temperature, and the variety. Under the conditions of these experiments the materials used appeared to be effective for a period of at least 15 days after the first application (Table II). The second spray did not appear to be effective for as long a period as the first application, for there was a gradual increase in the per cent of drop from the time of the second application until harvest. The data presented in Tables II and III are calculated on the basis of the total crop on the trees 2 days after the first spray was applied.

Gardner *et al.* (2) suggest that naphthalene acetic acid and naphthaleneacetamide are less effective at low temperatures. In view of this, the difference in effectiveness between the first and second sprays might be explained in part by the somewhat lower temperatures which occurred during the second period. During the first period the mean maximum temperature was 91 degrees F and the mean minimum was 60, while during the second period, the mean maximum was 85, and the mean minimum was 58.

TABLE II—PERIODICAL RATE OF DROP IN PER CENT

Treatment	Number of Trees	Period I					Period II				
		Days After First Spray					Days After Second Spray				
		5	8	12	15	18	7	11	14	17	20
Naphthalene acetic acid .001 per cent	4	.65	.37	2.3	1.8	3.3	1.3	3.1	5.3	6.7	7.9
Naphthaleneacetamide .001 per cent	4	1.25	.96	2.4	1.7	5.3	4.1	3.8	5.5	7.9	9.1
Check	4	3.1	3.0	5.7	3.2	7.2	6.8	9.4	9.0	6.9	5.1

There is no doubt that winds disturbed a normal course of events. Reference to Table II will reveal that the per cent drop, occurring

12 days after the first spray was applied, is rather high. This may be explained by a high wind (velocity 26 miles per hour) which occurred on September 6. Likewise on September 11, 16 days after the first application, the wind reached a velocity of 28 miles per hour, causing many apples to drop.

TABLE III—AVERAGE ACCUMULATED PER CENT DROP OF TOTAL CROP (SPRAYED AUGUST 26 AND SEPTEMBER 10)

Treatment	Number of Trees	Date									
		Aug 31	Sep 3	Sep 7	Sep 10	Sep 14	Sep 17	Sep 21	Sep 24	Sep 27	Sep 30
Naphthalene acetic acid .001 per cent...	4	.65	1.02	3.32	5.12	8.42	9.72	12.82	18.12	24.82	32.72
Naphthaleneacetamide .001 per cent.......	4	1.25	2.21	4.61	6.31	11.61	15.71	19.51	24.91	32.71	41.81
Check...............	4	3.1	6.1	11.8	15.0	22.2	28.9	38.3	47.3	54.2	59.3

Wormy Fruit:—It is generally believed that a large percentage of the fruits that are infested with codling moth larvae drop from the tree. It is probable that when the insect enters the apple certain conditions may be set up whereby the abscission layer forms and the fruit falls. Evidence in support of this view may be found in Table IV. It may be observed that, on the untreated trees, there was an average drop of 88 per cent of the fruits that were infested with the codling moth larvae. Furthermore, by comparing the check treatments in Tables I and IV, it will be noted that although a large per cent of sound apples dropped, the per cent of the wormy apples that fell was much higher. In view of this, it is interesting to observe the effect of the hormone sprays in preventing fruits infested with codling moth from falling. The data secured from these studies are presented in Table IV.

TABLE IV—EFFECTS OF NAPHTHALENE ACETIC ACID AND NAPHTHALENEACETAMIDE ON ABSCISSION OF WORMY APPLE FRUITS

Treatment	Number of Trees	Per Cent Wormy Fruit of Total Crop*	Replication				Average
			1	2	3	4	
Naphthalene acetic acid .001 per cent..................	4	9.3	72.0	35.1	69.7	56.1	58.2
Naphthaleneacetamide .001 per cent.................	4	8.7	76.8	59.4	71.7	74.3	70.5
Check.....................	4	9.5	94.4	65.7	96.4	95.7	88.1

*This figure was calculated, using only those fruits which had a worm in them. Stings were not included.

It will be observed that the results are very similar to those secured from the sound fruit, that is, both materials reduced the drop by significant proportions (odds, 100:1). The comparative effectiveness of these two materials was the same as for sound fruit, in that naphthalene acetic acid apparently was more effective (odds, 20:1) than naphthaleneacetamide. Reference to the data in Table IV will show further that although the materials were effective in reducing the drop of wormy fruits, the total per cent drop of these fruits was high. It there-

fore follows that these sprays do not appreciably increase the number of wormy fruits to be handled in the picking and grading processes.

Conclusions

Under the conditions of these experiments, both naphthalene acetic acid and naphthaleneacetamide used at the approximate strength of .001 per cent were effective in delaying the pre-harvest drop of Stayman Winesap apples. These materials were effective for a period of at least 15 days after the first application. A second spray apparently was not effective for as long a period as the first, possibly because of somewhat lower temperatures which occurred during the second period. The data indicate that these materials are effective in reducing the drop of apples which have been infested by the codling moth, but not to the extent that handling costs are appreciably increased. In this experiment naphthalene acetic acid was more effective than naphthaleneacetamide in reducing the pre-harvest drop. Since the above conclusions are based on only one year's data, this paper must be considered a progress report.

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The Use of Naphthaleneacetic Acid and Its Derivatives for Preventing Fruit Drop of Apple

By A. E. Hitchcock and P. W. Zimmerman, *Boyce Thompson Institute for Plant Research, Inc., Yonkers, N. Y.*

UNDER the conditions of our experiments pre-harvest sprays were effective in reducing drop in some cases and not in others. Five different substances and five varieties of apple were used. Varietal differences were encountered similar to those reported by others (3, 5, 6). No one derivative of naphthaleneacetic acid was noticeably more effective than another in comparative tests on the same trees. There were marked differences in the response of different trees of the same variety, and different branches on the same tree regardless of the treatment received. The results are based on counts made of 18,000 fruits.

Experimental Results

McIntosh:—On August 27, 1940, naphthaleneacetic acid, naphthaleneacetamide, naphthoxyacetic acid, and naphthoxyacetamide were applied at a concentration of 7.5 mg/l as sprays to different branches of tree No. 1-PK. Casein was used as a spreader in these solutions and also as a control spray. This treatment was repeated on October 3 on the same branches and again on October 11. The third spray solution was made up in a concentration of 15 mg/l instead of 7.5 mg/l. At this time (October 11) the naphthaleneacetic acid spray was applied also to branches not previously treated.

Several branches were used for growth substance treatment and for control sprays. At least for some of the treatments and also the controls, branches were selected in different locations so as to compensate for variability of normal drop in different parts of the same tree. Thus the average percentage drop of fruit shown in Figs. 1 and 2 was based upon several to many separate counts which were recorded on labels attached to individual branches. In addition, the percentage drop from the entire tree was obtained by counting periodically the fruits which had fallen to the ground, including those which had fallen before the spray was applied.

The procedure just described was used also for treatment of the other McIntosh trees except that the same substances or the same concentrations were not used in all cases. Casein was used according to the manufacturer's directions as a spreader for all solutions applied to tree No. 1-PK. Casein and 0.5 per cent Penetrol were used separately as spreaders for solutions applied to tree No. 1. Penetrol was used as the spreader for solutions applied to trees No. 2 and No. 3. Spray solutions were applied with a knapsack sprayer in these and in all other tests. Results of tests on potted tomato plants showed that the growth substance in the spray solutions was not inactivated by either Casein or Penetrol.

The percentage fruit drop varied considerably for different branches regardless of the treatment administered. Likewise the average percentage drop varied for any given treatment on the same tree and

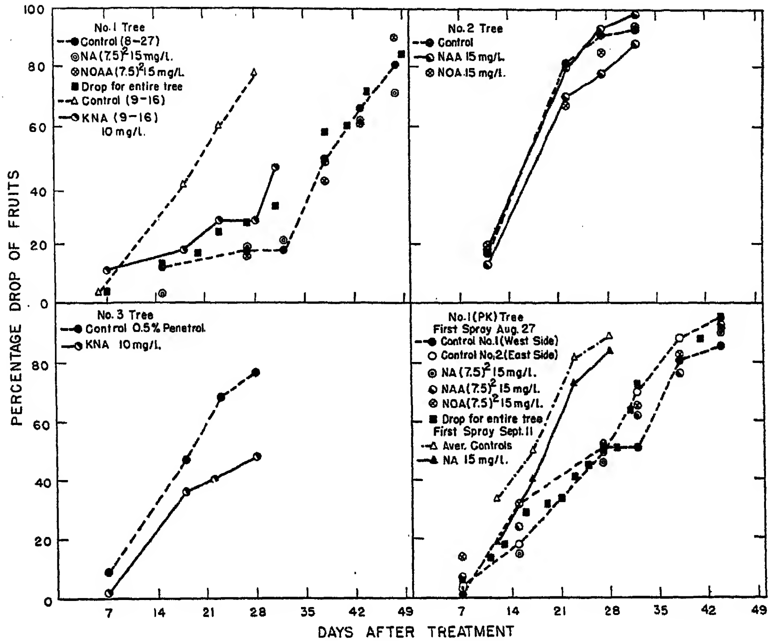

FIG. 1. Effect of growth substance sprays on fruit drop of McIntosh apple. A (upper left), B (upper right), and C (lower left), trees planted 1928. NA, naphthaleneacetic acid; NOAA, naphthoxyacetamide; KNA, potassium naphthaleneacetate; NAA, naphthaleneacetamide; NOA, naphthoxyacetic acid. D (lower right), tree planted 1924.

on different trees. Some of these variations are shown in Fig. 1. Differences between the percentage drop from the east and west sides of a tree are shown in Fig. 1, D for control branches. Variation in duplicate treatment is shown for naphthaleneacetamide in Fig. 1, B. In all other cases the average percentage drop is given.

Treatments started August 27 were not effective for reducing fruit drop during any part of the 6 weeks after the first spray was applied (Fig. 1, A and D). Of the sprays applied during the period September 11 to 16 potassium naphthaleneacetate was effective (Fig. 1, A and C), naphthaleneacetic acid slightly effective (Fig. 1, D), and naphthaleneacetamide not effective (Fig. 1, B). Since similar differences were obtained for a single substance, the variability in this case may be due partly to individual differences in trees (Fig. 1). Under comparable conditions it has been found that for other physiological responses naphthaleneacetic acid and its salt, ester, and amide derivatives are of about equal activity. The abscission response is probably not an exception.

Trees varied with respect to the time when fruit drop became noticeable and also with relation to the rate of drop. For example, tree No. 1-PK started dropping its fruit 10 to 14 days earlier than the other three trees and lost fruits thereafter at a fairly constant rate. The

differences in the rate of drop for the entire tree are shown for trees No. 1 and No. 1-PK in Fig. 1, A and D. On September 12 (16 days after treatment) tree No. 1 had lost 13 per cent of its fruit, whereas tree No. 1-PK had lost 29 per cent. Concentrations of 7.5, 10, and 15 mg/l were generally ineffective. A few small branches on tree No. 1 were sprayed September 16 with potassium naphthaleneacetate in concentrations of 100, 320, and 1,000 mg/l. These treatments appeared to be no more effective than the lower concentration of 10 mg/l used in the principal tests (Fig. 1, A) and applied at the same time. On the other hand these high concentrations produced no visible signs of injury on McIntosh. This is in contrast to the injurious effects on leaves of Stayman Winesap caused by solutions containing 320 or 1,000 mg/l of potassium naphthaleneacetate. Concentrations of naphthaleneacetamide, naphthoxyacetic acid, and naphthoxyacetamide greater than 15 mg/l were not used. Since naphthoxyacetic acid proved effective for inducing other hormone-like responses similar to those caused by naphthaleneacetic acid (4, 8), it is believed that the former substance should also be effective for reducing fruit drop if it is used in the proper concentration. For example, in recent tests naphthoxyacetic acid delayed abscission of flowers and petiolar stubs of tomato, caused parthenocarpic development of tomato fruits, and modified the patterns of tomato and *Mimosa* leaves.

Other Varieties:—The entire tree was sprayed with potassium naphthaleneacetate in concentrations of 10 to 50 mg/l after fruit drop had started. Penetrol was used at a concentration of 0.5 per cent as a spreader. Treatments used in this series of tests are shown in Table I. The percentage drop was based upon the number of fruits which had

TABLE I—NUMBER OF TREES SPRAYED (FOR RESULTS SEE FIG. 2)

Variety	Concentration KNA Mg/l					Total No. Trees
	0	10	12.5	25	50	
Baldwin	3	—	1	1	—	5
Stayman Winesap	3	—	2	2	1	8
Rhode Island Greening	2	—	1	2	—	5
Grimes Golden	5	1	1	1	2	10
Totals	13	1	5	6	3	

fallen from the entire tree. In addition, the percentage drop was determined for selected branches. However, in this case the values for branches on treated trees had to be compared with the values for branches on control trees. This is in contrast to the method of comparison used for McIntosh in which case treated and control branches were located on the same tree as well as on different trees.

Trees of all four varieties ranged from sparsely fruited to those heavily laden. The heavily fruited trees were not thinned as would normally have been the practice.

Data in Fig. 2 show that during the first 2 weeks after treatment the rate of drop was much more rapid on Grimes Golden and Rhode Island Greening than on Stayman Winesap and Baldwin. However, the treatments were generally ineffective on all four varieties. The variation in

the percentage drop for different control trees makes evaluation of the possible effectiveness of the treatments difficult. On the basis of the average percentage drop on control trees, the values for individual treatments show reductions up to 21 per cent. On the other hand a 21

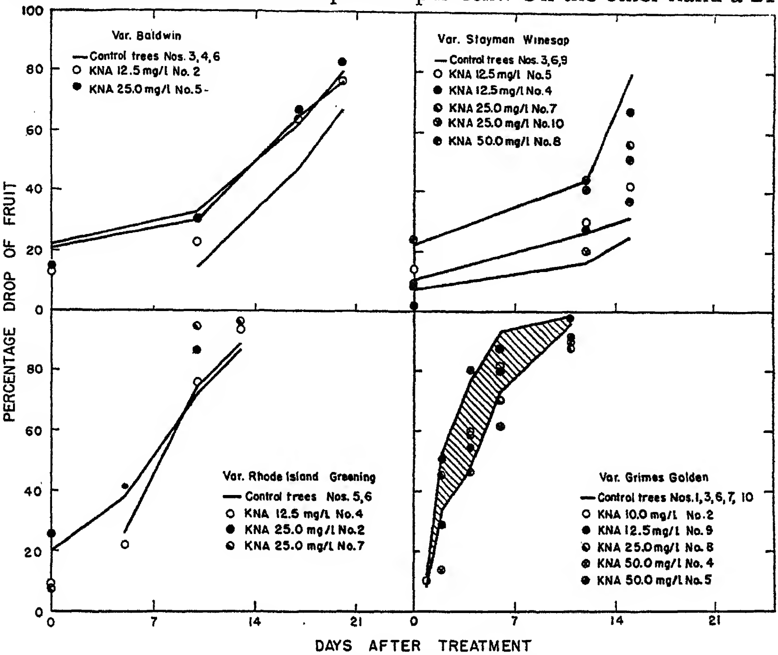

FIG. 2. Rate of fruit drop for different varieties of apple sprayed with different concentrations of potassium naphthaleneacetate. A (upper left) and C (lower left) sprayed October 4. B (upper right) sprayed October 9. D (lower right) sprayed October 3.

per cent *reduction* obtained with a 50 mg/l spray on one Grimes Golden tree is offset by the 18 per cent *increase* obtained with the same spray on another tree (Fig. 2, D). If, however, the entire range of values for controls as given in Fig. 2 is used as a basis for evaluating individual treatments, it will be seen that none of the values for the growth substance treatments falls sufficiently outside of the control range to appear noticeably significant (Fig. 2). Values for the average percentage drop for all treatments likewise are not essentially different from the average values for the controls. At least it may be said that the data in Fig. 2 show no pronounced favorable effects of the growth substance sprays.

Although the entire tree was sprayed in this series of tests (Fig. 2), the percentage drop was determined for some of the individual branches on certain trees of each variety. The percentage drop for different branches varied considerably as was shown for different trees in Fig. 2. In no case was there a reduction on treated branches of more than 16 per cent below the average value for counted control branches located on the several different trees.

In addition to branch counts on trees where all branches were sprayed, branch counts were made on two trees of Stayman Winesap for which data do not appear in Fig. 2. Thus on tree No. 1 the percentage drop values for nine different branches sprayed with 50 mg/l of potassium naphthaleneacetate were 0, 0, 0, 0, 18, 18, 25, 37, and 56 at the end of 15 days. Values for seven control branches on the same tree were 0, 26, 33, 40, 56, 56, and 74 per cent. The average reduction in fruit drop was 24 per cent. Similar counts for tree No. 2 showed an average reduction of only 6 per cent. Here again attention is called to the variation in fruit drop for individual branches on the same tree and on different trees.

Since with concentrations up to 50 mg/l there appeared to be no pronounced effect of concentration, the range was extended to 1,000 mg/l in a limited number of tests. Small branches of Stayman Winesap having up to 15 fruits were sprayed with potassium naphthaleneacetate in concentrations of 100, 320, and 1,000 mg/l. Fruits on these branches did not adhere for longer periods than in the case of branches treated with lower concentrations. Gardner *et al.* (1, 2, 3) obtained better results in most but not all cases with concentrations of 10 mg/l than with lower concentrations. Pronounced injury to most leaves was caused by the highest concentration (1,000 mg/l) and was proportionally less with the lower concentrations. About one-fifth of the leaves were injured by the 320 mg/l spray and minimum injury occurred with the 100 mg/l spray. The injury consisted of an abnormal yellowish coloration followed by progressive desiccation and browning of the tips and margins, and finally shriveling of the entire leaf. In contrast, the same sprays did not injure the leaves of McIntosh.

Own-Rooted Stayman Winesap:—In these tests approximately half of the tree was sprayed with naphthaleneacetic acid or potassium naphthaleneacetate in concentrations of 12.5, 25, or 50 mg/l. The other half was sprayed with 0.5 per cent Penetrol and served as a control. Otherwise the procedure was the same as that described for branch counts on McIntosh.

Data recorded in Table II show that spraying with naphthaleneacetic acid or potassium naphthaleneacetate reduced fruit drop on all six trees. The consistency of the response as well as the actual percentage reduction indicates that in this series of tests the growth substance spray was

TABLE II—Reduction in Percentage Drop of Fruit on Own-Rooted Stayman Winesap Sprayed October 11

	Concentration Naphthaleneacetic Acid, Mg/l												
	12.5				12.5*		25				50		Totals
Tree number	1		4		7		2		6		3		
Days after treatment	10	13	10	13	12	15	10	13	17	20	10	13	
Controls (0.5 per cent Penetrol)	28	41	42	69	12	38	14	44	75	85	17	67	532
Treated	13	28	0	56	5	5	9	33	43	57	6	37	292
Reduction in per cent drop	15	13	42	13	7	33	5	11	32	28	11	30	240

*K-salt.

effective. Although this appears to be the only series of tests here reported in which a uniformly positive effect was obtained, it is to be noted that there was considerable variation in the actual percentage reduction (Table II, last line). At the end of the first period of 10, 12, or 17 days the percentage reduction ranged from 5 to 42 per cent and for the last period of 13, 15, or 20 days the range in reduction was 11 to 33 per cent. The percentage drop for controls ranged from 12 to 75 per cent at the end of the first period of 10, 12, or 17 days (Table II). Such consistent differences between control and treated halves of the tree were clearly evident by visual inspection, but the actual gains due to treatment were much lower than the 60 to 80 per cent reductions reported by other workers (3, 7).

Crataegus mollis Scheele:—On September 24, potassium naphthaleneacetate was applied at a concentration of 10 mg/l to certain branches of several trees which were heavily laden with fruit. More pronounced variation in fruit drop occurred in this series of tests than was mentioned for apple. For example, on October 18 the treated branches of tree No. 1 had retained most of their fruit whereas there was scarcely a fruit to be seen on the non-treated branches which constituted the major portion of the tree. On tree No. 2 some treated branches had retained over 50 per cent of their fruit while others had lost all of their fruit. Tree No. 3 received no treatment, yet at the end of 24 days it was similar in appearance to tree No. 1 (above), having lost practically all fruit except on one branch which at this time was still heavily laden.

Summary

Results with pre-harvest sprays applied to five varieties of apple showed favorable effects in some cases but not in others. Besides varietal differences there was considerable variation in fruit drop from different trees of the same variety and from different branches of the same tree, regardless of treatment. No single one of the derivatives of naphthaleneacetic acid was noticeably more effective than the others. Concentrations of 25 to 50 mg/l appeared to be no more effective than concentrations of 7.5 to 15 mg/l.

In the region of Yonkers, New York, the season of 1940 was favorable for the early coloring and maturing of such red-fruited varieties as McIntosh, Stayman Winesap, and Baldwin. The crop of fruit could have been harvested in most cases before a 20 per cent drop had occurred. The generally cool weather which was favorable for early coloration of fruit may have been unfavorable for the action of growth substances in reducing drop. For other types of growth substance responses temperature is known to be an important limiting factor.

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Further Studies with Sprays in Controlling Pre-Harvest Drop of Apples

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EXPERIMENTS performed in 1939 (2, 3) with growth-substance sprays proved successful in delaying the pre-harvest drop of apples, and results obtained during that year gave considerable promise that the method would be a practical control measure for orchard use. The present report covers certain phases of the problem upon which additional information seemed desirable.

WILLIAMS EXPERIMENT

The purpose of this experiment was twofold: (A) To compare the effectiveness of compounds closely related to naphthaleneacetic acid (treatments 5, 6, and 7, Table I) with that of naphthaleneacetic acid and naphthaleneacetamide (treatments 2, 3, and 4, Table I); and (B) to test the effectiveness of chemical compounds combining the a-naphthalene methyl group of napthaleneacetic acid with the thiocynate group (1) with the possibility that such compounds might be effective in both abscission inhibition and increased color development (treatments 8 and 9, Table I).

These experiments were conducted in a block of 14-year-old Williams trees located in the vicinity of Salisbury, Maryland. Spray applications (10 gallons per tree) were made July 16 with commercial spray equipment of the portable type; each treatment was applied to five trees randomized throughout the block. The fruit when sprayed was hanging firmly, and color development was negligible. By July 20, however, dropping was well under way with fruit generally beginning

TABLE I—EFFECTIVENESS OF DIFFERENT CHEMICAL COMPOUNDS ON DROPPING AND COLOR OF WILLIAMS EARLY RED

Treatment Number	Compounds Used*	Spray Concentration (Per Cent)	Average Crop Per Tree Before Spraying (Bus)	Average Per Cent Drop of Original Crop (S. Em.)	Total Average Color When Harvested (Per Cent)
1	Unsprayed	—	8.8	44.3 ± 7.90	—
2	A—naphthaleneacetic acid	.001	9.3	1.6 ± 2.94	52 ± 1.89
3	A—naphthaleneacetic acid	.0005	8.2	0.8 ± 0.20	—
4	A—naphthaleneacetamide	.001	9.0	2.2 ± 1.50	52 ± 4.18
5	Tetralin-6-acetamide	.002	9.6	17.7 ± 6.44	—
6	B—naphthoxyacetic acid	.001	10.0	41.2 ± 5.77	—
7	A—naphthalene acetonitrile	.001	9.7	51.5 ± 3.96	—
8	A—naphthalene methyl thiocynate	.002	8.1	45.4 ± 11.60	—
9	A—naphthalene methyl isothiocynate	.002	9.1	49.2 ± 8.16	—
10	Sodium thiocynate	.10	9.5	58.2 ± 9.96	—
11	Treatment No. 2 plus No. 7	—	8.6	0.6 ± 0.11	48 ± 4.30
12	Treatment No. 2 plus No. 8	—	8.4	1.0 ± 0.91	51 ± 4.22
13	Treatment No. 2 plus No. 9	—	10.3	0.5 ± 0.18	50 ± 3.31
14	Treatment No. 2 plus No. 10	—	9.5	0.8 ± 0.20	46 ± 8.30
15	Treatment No. 4 plus No. 7	—	10.0	1.8 ± 0.64	50 ± 3.00
17	Treatment No. 4 plus No. 10	—	7.3	1.9 ± 0.47	47 ± 2.43

*Acknowledgment is made to Mr. Franklin D. Jones of American Chemical Paint Co., Ambler, Pennsylvania, for supplying the above chemicals.

to exhibit a red blush. The first picking was made July 25 with the remainder of the fruit harvested 4 days later.

Reference to Table I shows naphthaleneacetic acid and naphthaleneacetamide to be the only treatments highly effective in retarding fruit drop. Drop was negligible in all cases where these materials were used alone or in combination with other chemicals. Tetralin-6-acetamide with a total average drop of 17.7 per cent suggested a partial retardation and was further tested in experiments to be described later. Of interest is the fact that a concentration of .0005 per cent naphthaleneacetic acid gave as good control as .001 per cent.

As is seen in Table I, degree of red color was essentially the same for all treatments on which color records were taken. Due to excessive fruit drop in treatments 5 to 10 inclusive, fruit color at harvest time was not comparable to other treatments and is therefore not included. The sodium thiocynate produced the only noticeable difference in quality of color. Where this compound was used both alone and with hormone chemicals, the fruit, while having no more total color, was of a definite pinkish cast and was noticeably more mature at harvest time, a condition probably responsible for the very heavy drop (58 per cent) where sodium thiocynate was used alone. Of significance also in connection with this treatment was a high percentage of the fruit showing definite spray burn in the form of brown flecks on the surface of the fruit. Failure to obtain increased color with sodium thiocynate, as reported by Dustman and Duncan (1), was possibly due to the lateness of application.

McIntosh Experiment

In 1939, hormone sprays applied to McIntosh in western New York (2) indicated an effective period of 8 to 10 days. These results suggested that if additional retardation of drop is desired, a repeat application could be made 4 or 5 days following the first application. During the past season an experiment was designed to obtain information on this phase of the problem. The trees used were 15-year-old McIntosh located at Beltsville, Maryland, and carrying an average crop of 10 bushels per tree. Applications of a-naphthaleneacetic acid were made as indicated in Fig. 1.

As can be seen from Fig. 1, all treatments were generally effective 11 days following the first spray application. At that date the total drop resulting from the single spray treatment was only slightly greater than that from the dual applications. Following the 11th and 12th days, the curves in Fig. 1 show a sharp trend upward irrespective of treatment. As at the point indicated in the graph, all trees, excepting checks, were again sprayed with .0005 naphthaleneacetic acid in order to ascertain if it is possible to stop fruit drop once it is well under way. The results clearly show that this treatment was not effective and indicate further that if the changes resulting in abscission have advanced beyond certain limits, the hormone spray is ineffective in retarding the process, and dropping results at about the same rate as if no spray was applied.

Of interest is the fact that the treatment which included a repeat application 7 days following an initial application prolonged the effec-

tive period only 1 to 1½ days beyond that resulting from the single application treatment. In this instance it seems likely that when the repeat spray was applied, abscission processes were so well defined in such a large proportion of the fruit that only a slight effect resulted. That the "3-day repeat treatment" was somewhat more effective than the 7-day treatment would seem to lend support to the above interpretation. The slightly better results of the 2-hour repeat spray as compared with the single spray was no doubt due to a more complete spray coverage.

In this experiment with McIntosh, little benefit was derived from applications following the initial one. With this variety the maximum effective period seems to be generally from 10 to 12 days with one application, if accurately timed. Repeat sprays would seem to be of doubtful value in extending this period except in cases where the initial spray was applied too far in advance of maturity.

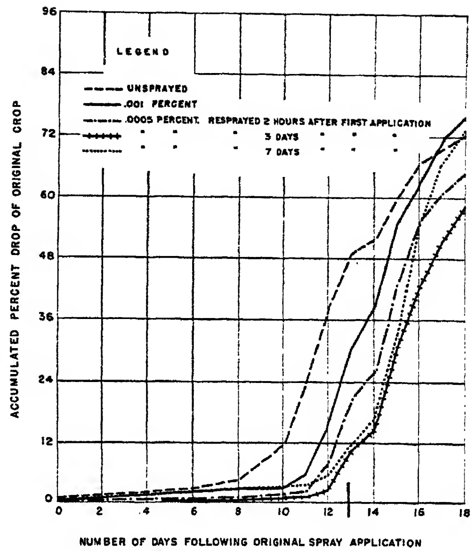

FIG. 1. Effect of repeat spray applications of naphthaleneacetic acid on pre-harvest drop of McIntosh apples. Data represent an average of five randomized trees for each treatment. Means with standard errors for each treatment (in order given under legend) 12 days after initial application are as follows: 38.5 ± 1.92, 15.0 ± 4.16, 7.8 ± 2.20, 3.0 ± 0.55, 5.7 ± 1.97.

In order to obtain the greatest benefit in both intensity and duration of effect, it is apparently necessary to spray just at the beginning of fruit drop. From the practical standpoint, such a procedure may be difficult to execute. One alternative would be to spray somewhat ahead of the normal drop when the fruit is still firmly attached. If it developed later that this application was made too far ahead of drop and it seemed advisable to delay harvest beyond the protective period of this spray (10 to 12 days), a second spray could be applied 7 or 8 days following the first.

Delicious Experiment

The directions for use accompanying all of the proprietary commercial preparations at the present time are calculated to give a spray solution with a .001-per cent concentration of the growth substance. Quantities of one-fourth to one-half this amount have proven effective in many instances, but data are lacking as to the relative differences

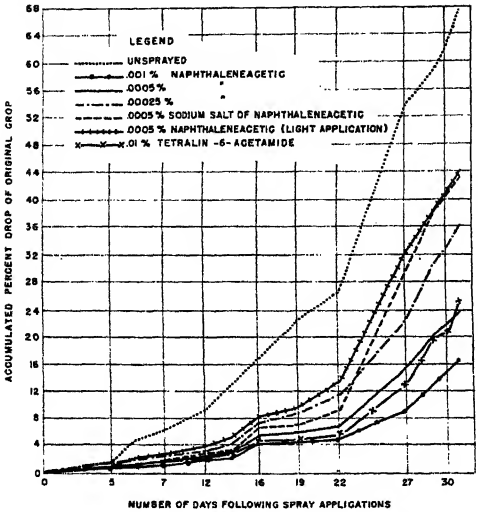

FIG. 2. Effect of different spray treatments on pre-harvest drop of Delicious apples. Data represent an average of five randomized trees for each treatment. Means with standard errors for each treatment (in order given under legend) 16 days after spraying are as follows: 17.0 ± 2.36, 4.4 ± 0.71, 5.6 ± 1.34, 7.4 ± 1.67, 6.8 ± 1.30, 8.4 ± 1.37, 4.7 ± 1.26.

in both duration and intensity of effect at the different concentrations.

Treatments indicated in Fig. 2 were applied to 15-year-old Starking trees growing in the station orchard at Beltsville, Maryland. The normal harvest date for this variety was about September 25, 14 days after spraying. At that time the drop for .001, .0005, and .00025 per cent naphthaleneacetic acid treatments was in the ratio of 1.0:1.3:1.8, respectively. When the fruit was harvested October 11, 30 days after spraying, the drop for these same treatments was in the ratio of 1.0:1.4:2.1. The degree of effectiveness increased somewhat with increasing concentration, but approximately the same relationship between concentrations existed throughout the 30-day period following the spray applications. In this experiment both the .001 and .0005-per cent sprays of naphthaleneacetic acid gave satisfactory delay in fruit drop for 22 days. Whether or not the greater concentration will give enough better results with most varieties to justify its use remains to be established.

In this experiment, a treatment was included in which the trees received a light spray application of 5 gallons per tree of .0005-per cent concentration of naphthaleneacetic acid. This treatment is to be compared with the one receiving the same concentration but more thoroughly applied (using 10 gallons per tree). The results given in Fig. 2 show the light application to be just one-half as effective in retarding drop. These results serve to emphasize that the control with these sprays can be no more effective than the coverage given.

Of interest in Fig. 2 is the sodium salt of naphthaleneacetic acid treatment. Until 15 days following application, this compound gave results identically the same as naphthaleneacetic acid of similar concentration. Following this date, however, the acid was significantly more effective than the sodium salt in prolonging the period of protection.

Tetralin-6-acetamide used at .01 per cent concentration proved very effective in delaying drop (Fig. 2). It will be recalled that an .002

per cent concentration of this compound was partially effective in controlling the drop with Williams (Table I).

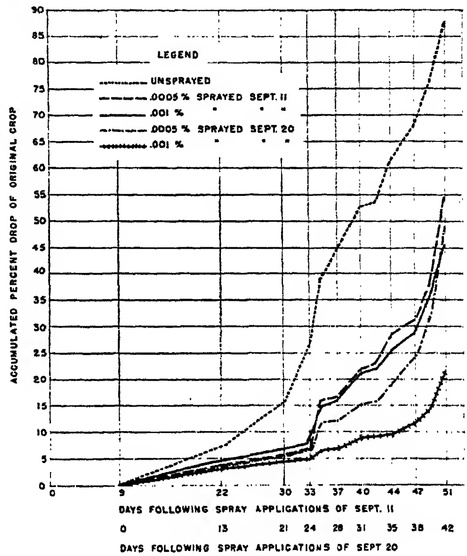

Fig. 3. Effect of different spray treatments on pre-harvest drop of Stayman Winesap apples. Data represent an average of five randomized trees for each treatment. Means with standard errors for each treatment (in order given under legend) at normal harvest date (October 16) are as follows: 39.1 ± 6.15, 16.1 ± 2.70, 14.9 ± 3.43, 11.8 ± 1.73, 6.5 ± 0.19.

Stayman Winesap Experiment

Single applications of .0005 and of .001 per cent naphthaleneacetic acid were made on 9-year-old Stayman Winesap trees growing in the station orchard at Beltsville, Maryland, some of the trees being treated on September 11 and others on September 20. Both spraying dates were well in advance of harvest, and no fruit drop was recorded until September 22. The results of this test are given in Fig. 3.

By October 18 the fruit was highly colored, yet not over-mature. On this date the September 20 sprays (28 days after application) were considerably more effective than the sprays of September 11 (37 days after application). While the data show a relatively long period of effectiveness in the case of this variety, they indicate that spray applications should not be made too far ahead of harvest for best results.

It is to be noted that at 42 days after application the percentage of drop for the .001 per cent application of September 20 was approximately equal to that for the same number of days following the September 11 application of this strength; but the latter application had held the drop under somewhat better control during the period between 33 and 40 days after application. While the stronger spray showed a slight tendency toward greater effectiveness than the weaker one when applied at the earlier date, it was significantly superior in the later treatment.

York Imperial and Rome Beauty Experiments

Experimental sprays (.001 per cent naphthalene acetic) were applied to York Imperial and Rome Beauty as late as October 15, shortly before the normal harvest date for these varieties. Though little or no drop had occurred up to this time, the sprays had little effect in retarding a heavy drop which set in about October 20 and continued

until the fruit was harvested. A possible explanation for failure in this case would seem to be the very low physiological activity of the leaves and other tissues at this late date. It is probable that, had these trees been sprayed two weeks earlier, good effect would have been obtained.

Effect of Sprays on Fruit Maturity

With summer varieties of apples, the fruit is likely to become overmature if allowed to remain on the tree even a few days beyond the normal harvest period. In the Williams experiment described above, the fruit became overripe and mealy on many of the trees before harvest was completed. Hormone spray so completely controls dropping with this variety that the early maturing fruits remain on the tree more or less indefinitely. If these fruits are not harvested within a day or two after they would have normally dropped if not sprayed, overmaturity develops, particularly under high temperature conditions.

Water core proved to be a serious factor in the Stayman Winesap and the Delicious experiments, becoming evident a week or more after the normal harvest period.

If harvest is delayed too long with some varieties, losses from overmaturity may offset any advantage obtained in added color. With many varieties it is likely that the harvest sprays will prove to have their greatest value in merely protecting the fruit grower from losses from dropping before and during the normal picking operation.

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Effect of Scoring and of A-Naphthyl Acetic Acid and Amide Spray Upon Fruit Set And of the Spray Upon Pre-Harvest Fruit Drop

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STARKING apple trees, 14 years of age, growing in an orchard owned and operated by the Horticultural Department at Lafayette, Indiana, had failed to set a full crop of fruit in any season prior to 1940. In May, 1940, two types of treatment (scoring and a-naphthyl acetic acid spray) were given selected trees in an effort to affect set of fruit.

Fruit Set

Scoring:—On May 5 and 6, a total of 22 matched pairs of main scaffolds and secondary branches located on 12 of the Starking trees were selected for a study of the effect of scoring upon fruit set. One-half of these paired branches were scored and the other 22 were left as untreated checks. Scoring was accomplished by cutting, with a sharp knife, three rings about 1 inch apart around each treated branch, making the cut deep enough to completely sever the bark. The bark rings were not removed from the branches. The scoring wounds were covered with grafting wax. The blossoming spurs were counted at time of treatment. There were 5,871 blossom clusters on the scored branches and 5,820 clusters on the untreated branches. The flowers were in a full "pink" stage of development at the time.

During the second week of July, a record was taken of the number of clusters setting one or more fruits. On the scored branches, 1,586 clusters, or 27.0 per cent of the total, set 1,685 fruits. On the untreated branches, 1,379 clusters, or 23.7 per cent of the total, set 1,428 fruits.

a-Naphthyl Acetic Acid and Amide Sprays:—Ten of the 14-year-old Starking trees were selected for spray treatment. These trees were divided arbitrarily into "halves." These halves were rotated to compensate for exposure. Interfering branches were removed to make it possible to manipulate a large shield in the centers and tops of these 10 trees to allow thorough spraying of desired portions without danger of drift of the spray to the so-called "unsprayed" halves. This shield was constructed by covering a light frame work with a heavy muslin sheet.

On May 13, when about 90 per cent of the flowers were open, 0.001 per cent a-naphthyl acetic acid spray was applied to "halves" of three trees; 0.005 per cent a-naphthyl acetic acid to "halves" of five trees, and 0.005 per cent a-naphthyl acetamide to "halves" of two trees. The 0.001 per cent a-naphthyl acetic acid spray contained 0.5 per cent of ethyl alcohol while the 0.005 per cent spray of a-naphthyl acetic acid and of a-naphthyl acetamide contained 1.0 per cent of ethyl alcohol. The acid and amide crystals were dispersed in the alcohol before addition to the spray tank.

Fruit set on the treated and untreated halves was recorded in early July after completion of the June drop. Records were as follows:

a-Naphthyl Acetic Acid 0.001 Per Cent:—Of the 5,243 treated clusters, 1,530, or 29.2 per cent, set 1,656 fruits. There were 3,652 untreated check clusters of which 1,258, or 34.4 per cent, set 1,312 fruits. This represents a reduction of 15.1 per cent in the number of clusters setting fruit as a result of treatment.

a-Naphthyl Acetic Acid 0.005 Per Cent:—Of the 7,572 treated clusters, 673, or 8.9 per cent, set 772 fruits. There were 6,991 untreated clusters, of which 2,494, or 39.9 per cent, set 3,063 fruits. The apparent reduction in clusters setting fruit, following treatment, amounted to 77.7 per cent.

a-Naphthyl Acetamide 0.005 Per Cent:—There were 2,054 treated clusters of which 656, or 22.2 per cent, set 698 fruits. Of the 2,191 untreated clusters, 734, or 33.5 per cent, set 816 fruits. The number of clusters setting fruit was reduced 34.0 per cent by the treatment.

Harvest Sprays

Two commercial "harvest sprays" were used in separate tests at dilutions suggested by the respective manufacturers. The tests were conducted in two orchards owned and operated by the Purdue University Agricultural Experiment Station, one located near Bedford, in southern Indiana, and the other near Lafayette, in the northern half of the state. Two varieties, Delicious and Rome, were included in the Bedford tests; and three varieties, McIntosh, Jonathan and Delicious, were sprayed in the Lafayette orchard. In the large scale test with Delicious at Lafayette, entire trees were sprayed. In the other tests, arbitrary halves of the test trees, rotated to compensate for exposure, were sprayed. No shield was used in the trees during the application of the spray. Wind conditions at the time of spraying were such, however, that there was no significant drift of spray to the so-called unsprayed halves which served as checks. The rate of application of the spray ranged from 0.40 to 0.50 gallons of material for each year in age of tree. In all cases, a portion of the spray was applied from beneath the tree (inside-outside application).

McIntosh (Lafayette):—Halves of 16 vigorous trees, 15 years of age, were sprayed August 30. A color picking was made on September 11 and harvest was completed on September 17 and 18. While drop records were taken only at time of harvest, from frequent observation the rate of drop of fruit appeared to be approximately equal from treated and untreated halves throughout the period of the test. Rotation of treated portions nullified the effect of exposure upon fruit drop. Regardless of treatment, however, heaviest drop occurred from the south and southeast portions of the trees. Final harvest records showed a loss, by dropping, of 26.9 per cent of the sprayed fruits and 32.7 per cent of the unsprayed apples from these 16 McIntosh trees, or 17.7 per cent less drop from sprayed portions.

Jonathan (Lafayette):—Halves of 25 trees were sprayed. The trees were 30 years of age and in good vigor. A total of 16.7 per cent

of the sprayed and 18.9 per cent of the unsprayed Jonathan apples dropped, a difference of 11.6 per cent in favor of the sprayed portions.

Delicious (Lafayette):—Alternate rows of 18-year-old trees in the soil management orchard at Lafayette were sprayed on September 19. The spray was applied to 70 entire trees and an equal number were left unsprayed for comparison. The crop was extremely variable, ranging from little or no fruit to a heavy crop. The application averaged 7 gallons a tree. Harvest was completed October 5 and 6. The dropped fruit under the sprayed trees totaled 1,382 pounds, or 9.9 per cent; and under the unsprayed trees 3,932 pounds, or 27.8 per cent of the total crop. Spraying reduced fruit drop by 64.3 per cent.

Delicious (Bedford):—Halves of 14, 28-year-old trees were sprayed on September 13 and the fruit from treated and untreated portions was harvested on September 27. Drop of fruit from sprayed and unsprayed halves amounted to 5.0 per cent and 21.8 per cent of the total crop, respectively, a reduction, by spraying, of 77.1 per cent in the amount of fruit drop.

Rome (Bedford):—On September 13, halves of 17, 25-year-old trees received harvest spray. The fruit was harvested on October 5. A total of 6.1 per cent of the sprayed fruit and 15.8 per cent of the unsprayed fruit dropped. Drop of fruit was reduced 55.1 per cent by spraying.

Since little fruit had dropped from the Rome trees sprayed earlier, eight additional Rome trees received similar treatment on September 20. The fruit was harvested on October 5. The drop of sprayed fruit amounted to 7.5 per cent and, of the unsprayed fruit, 21.4 per cent of the total crop. Fruit drop was reduced 65.0 per cent by spraying. Both sprayed and unsprayed fruit was loosening by October 5, so that harvesting was then necessary to prevent heavy drop.

Summary and Discussion

Under conditions existing at Lafayette, Indiana, in 1940, scoring resulted in only a slight increase (13.9 per cent) in the number of clusters on 14-year-old Starking apple trees setting fruit. When such a high percentage (23.7) of the clusters on untreated branches set fruit, only a slight response to scoring might be expected. Of the clusters on treated branches, 27.0 per cent set one or more fruits.

Moderate decreases in fruit set followed the application of full blossom sprays containing 0.001 per cent a-naphthyl acetic acid or 0.005 per cent of a-naphthyl acetamide. The reductions amounted to 15.1 per cent and 34.0 per cent, respectively. A very heavy decrease (77.7 per cent) resulted from the application of a 0.005 per cent spray of a-naphthyl acetic acid to the open flowers. Very serious injury to the immature leaves, epinasty and scorching followed by leaf drop, occurred following the application of the spray containing 0.005 per cent of the acid. Some injury was visible following the use of the weaker strength (0.001 per cent) of the acid, but none was visible on trees sprayed with the acetamide.

The use of harvest sprays reduced materially the drop of mature

fruits of Rome and Delicious. No very significant results followed the application of the sprays to Jonathan and McIntosh.

The junior author has observed, in most McIntosh fruits studied at Lafayette, that pith abscission has been initiated by the time there is a noticeable striping of the fruit. Whether the application of growth promoting substances after the initiation of pith abscission will delay the process of abscission in McIntosh stems is still an open question. Possibly extremely heavy applications of spray may influence the rate of the process in this variety. The authors recognize the fact that ½ gallon of spray for each year in age of tree might be considered by some workers to be a light application.

The fact that varieties in which the initiation of abscission in bark tissues generally precedes pith abscission respond most readily to harvest sprays indicates an important relationship between mode of abscission and reaction to the effectiveness of these sprays. The effect of the spray is merely to delay the natural chemical changes in cell wall substances resulting in separation of cells and ultimate drop of fruit.

The Effect of Hormone Sprays on the Harvest Drop of Apples

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Abstract

This material will be published in full in an Experiment Station Bulletin.

A NUMBER of tests of the use of hormone sprays to lessen harvest drop of apples were conducted. Several commercial preparations and pure napthalene acetic acid were used. Concentrations of actual hormone varied usually from 2½ to 10 parts per million parts of water. From 15 to 35 gallons of spray per tree, according to its size and crop, were applied at approximately 400 pounds pressure. Tests were made in several orchard blocks mostly with the McIntosh variety, but including also Duchess, Wealthy, Baldwin, and an unknown variety which always drops badly. Drops were gathered and counted, usually daily, and the number of apples picked from each tree was calculated.

With Duchess and the unknown variety, the spray was very effective, holding the apples beyond the proper picking time while the check trees dropped very heavily. With Wealthy, the results were much less striking and the differences in drop between the sprayed and the check trees were not apparent in the field. Analysis of the data, however, practically always shows some benefit from spray applications. The tests on Baldwin were complicated by cold weather. Several freezes either masked the influence of the hormones or the influence was not marked.

In general, with McIntosh also, the effects of the sprays on lessening drop were usually not discernable in the field. The data show considerable variability of effectiveness in the different tests. Influencing factors included time of application, amount of hormone in the spray material, particular orchard or block of trees used for the test, and possibly the hormone carrier or, in other words, the commercial brand. Considering the time during which the hormones were effective, the check trees in almost every case dropped more heavily than the sprayed trees. Expressed as per cent of total crop, the drop from check trees was as much as three to four times as much as that from sprayed trees, though usually the difference was much less.

The effect of hormone applications was usually evident by the third or fourth day and persisted for about 8 to 12 days. Hormone concentrations of 10 parts per million were usually more effective than lower concentrations. In one test on Baldwin, using a 10 parts per million spray and one higher, the latter seemed more effective. There seems to be a probability that concentrations higher than 10 parts per million may be necessary for desired drop control with some varieties, possibly including McIntosh. The addition of a small amount of summer oil served to increase effectiveness.

It is doubtful if many of the trials on the McIntosh checked drop

enough to be commercially profitable. In some of these tests the spray was applied too early for maximum effect in this year of light drop. It is possible that in a year of more severe dropping, the hormone sprays would be more effective and their use more profitable. The use of these sprays on McIntosh should encourage growers to delay picking until better size and quality are attained. Most McIntosh are picked too early.

The size of the crop on the trees is an important factor in determining profits from hormone spraying. With a heavy crop the number of bushels saved is larger while the expense is little more than with a light crop. Comparison of percentage figures may lead to a false interpretation of spraying benefits. In other words, marked decreases in percentage of drop do not necessarily mean that spraying is profitable.

Preharvest Apple Spraying and Fruit Abscission[1]

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DELAYED abscission of apple fruits following the application of plant growth substances was reported by Gardner, Marth, and Batjer (1) and substantiated by later work (2, 3). Very dilute solutions of naphthalene acetic acid and naphthalene acetamide were sprayed on the trees just as fruit drop began. Gardner and his co-workers found that with McIntosh apples, the period of effectiveness of a single application lasted from 8 to 10 days, whereas with other varieties beneficial effects were noted as long as 3 weeks after spraying.

The possibility of reducing fruit drop as well as increasing the color, size, and flavor of apples by allowing them to mature fully on the trees suggested the use of such sprays by the commercial growers. Consequently, many proprietary compounds containing the active plant growth ingredients, naphthalene acetic acid or naphthalene acetamide, have appeared on the market during the past season.

The purpose of the study described here was to determine the effectiveness of naphthalene acetic acid on McIntosh apples under Rhode Island climatic conditions and to test the effectiveness of several commercial sprays on Baldwins and Rhode Island Greenings.

MATERIALS AND METHODS

McIntosh Experiment:—Crystalline naphthalene acetic acid was used for the McIntosh study. This was dissolved in 95 per cent ethyl alcohol and diluted with water. The resulting stock solution was then poured directly into the spray tank. An area containing 32 trees was divided into eight plots with four trees in each. The seven treated plots were sprayed with concentrations varying from .0001 per cent to .0010 per cent, with one, two, and three applications, and with intervals between sprays ranging from 3 to 8 days. The sprays were applied with a power machine at a pressure of 300 pounds. The amount of spray applied to each tree varied with the quantity of apples on the tree, but in general, in all experiments from 1¼ to 1½ gallons of spray were used for each bushel of apples.

Rhode Island Greening and Baldwin Experiments:—Blocks of 28 Rhode Island Greening and 18 Baldwin trees were divided into plots of four and three trees each, respectively. These trees were then sprayed with commercial compounds containing the plant growth ingredients. Plots treated with a .001 per cent concentration of naphthalene acetic acid and check plots receiving no spray were included in each experiment. In applying the sprays the manufacturers' recommendations were followed in each case, all the compounds being soluble in water.

PRESENTATION OF DATA

McIntosh Experiment:—The McIntosh trees were sprayed September 20, and daily records were taken of the number and weight of

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apples that dropped from each tree. These daily records showed that the effect of a one-application spray at a .001 per cent concentration persisted for a 10-day period from the date of spray application. The data for the percentages of fruit drop from the trees for the 10-day period are presented in Table I. The means of the percentage fruit

TABLE I—PERCENTAGE DROP FROM McINTOSH TREES SPRAYED WITH NAPHTHALENE ACETIC ACID AS OF SEPTEMBER 30 (TREES WERE SPRAYED SEPTEMBER 20)

Treatments			Trees				
Per Cent Concentration	Applications	Days Interval	1	2	3	4	Mean
.001	1	—	6.3	7.1	4.3	4.1	5.5
.001	2	8	13.4	3.1	3.1	4.7	6.1
.0005	2	6	7.4	5.6	2.9	4.7	5.2
.0005	2	8	16.8	6.1	4.3	5.3	8.1
.00025	2	6	15.1	9.3	5.5	5.5	8.9
00025	2	3	20.1	5.5	3.2	5.3	8.5
.0001	3	3	14.3	5.9	4.2	5.9	7.6
Check	No spray	—	25.5	27.9	9.5	13.4	19.1

Difference necessary for significance—5.1 per cent.

drop of all sprayed plots are significantly less than the mean of the unsprayed plot. This would indicate that all the sprays brought about delayed fruit abscission.

The crop was, however, not harvested at this time, but record taking was continued for four more days. At this time, the trees receiving one application, as well as the trees receiving two applications at lower concentrations, were dropping their fruit at the same rate as the unsprayed trees. It was apparent that some of the sprays were no longer effective in delaying fruit abscission. The percentage drop from all trees up to the termination of the study is given in Table II. Even

TABLE II—PERCENTAGE DROP FROM McINTOSH TREES SPRAYED WITH NAPHTHALENE ACETIC ACID (SPRAYED SEPTEMBER 20, PICKED OCTOBER 4)

Treatments			Trees				
Per Cent Concentration	Applications	Days Interval	1	2	3	4	Mean
.001	1	—	19.7	23.6	11.7	14.2	17.3
.001	2	8	29.1	6.3	8.1	9.8	13.3
.0005	2	6	14.8	11.6	5.7	8.6	10.2
.0005	2	8	34.1	16.6	10.3	12.0	18.3
.00025	2	6	26.3	16.7	11.4	14.6	17.3
.00025	2	3	41.3	18.8	11.8	14.4	21.6
.0001	3	3	21.6	9.0	8.9	14.1	13.4
Check	No spray	—	41.8	44.0	16.0	23.4	31.3

Difference necessary for significance—8.1 per cent.

after 14 days from the date of the first application, all the sprayed plots showed means of percentage fruit drop significantly less than the mean of the unsprayed plot. It is of further interest to note that two applications at concentrations of .001 and .0005 per cent applied 6 days after the first are effective in delaying fruit abscission for 14 days. A grower equipped so that he can harvest his McIntosh in 10 days might well use one application of .001 per cent, where as a

grower needing 13 to 14 days to harvest his crop might use two applications at a concentration of .0005 per cent with an interval of 5 to 6 days between applications.

Rhode Island Greening Experiment:—The Greenings were sprayed September 11, and the apples were picked October 1. The apples had not begun to drop when the crop was picked, and consequently, no significant differences existed between the means of percentage fruit drop of the sprayed or unsprayed plots. The usual picking season in Rhode Island for this variety extends from September 1 to September 15. While color is not a factor to be considered in the harvest of Greenings, the apples are less susceptible to storage scald when allowed to mature fully on the trees. Any practice that would delay fruit abscission would aid materially in overcoming this storage trouble. The unsprayed trees held their fruit as well as the sprayed trees, and the amount of fruit abscissed by October 1 was only a small percentage of the total crop.

Baldwin Experiment:—The Baldwins were sprayed October 10, and the apples were picked October 26. At the time of spray application, there was no appreciable amount of fruit drop, however, at the time of fruit harvest, there was very little fruit remaining on the trees. Two days after the sprays were put on, records including the number and weight of apples dropped were obtained and were continued on alternate days until the fruit was harvested. The percentage drop from the Baldwin trees is presented in Table III. No significant differences existed between the percentage drop means of any of the plots. The sprays were of no apparent value in preventing fruit abscission. The usual picking season for Baldwins in Rhode Island is from October 1 to October 15. The sprays were applied late in the season. This may, in part, account for their apparent ineffectiveness.

TABLE III—Percentage Drop from Baldwin Trees Sprayed with Commercial Compounds (Sprayed October 10, Picked October 26)

	Treatments					
Tree	Parmone	Fruitone	Stop-Drop	App-L-Set	Naphthalene Acetic Acid	No Spray
1	55.3	63.5	82.2	49.5	48.6	90.2
2	49.8	81.7	80.1	91.8	54.2	65.5
3	81.6	71.9	65.3	73.4	78.8	78.3
Mean	62.2	72.4	75.9	71.6	60.5	78.0

Conclusions

Preharvest sprays of naphthalene acetic acid at varying concentrations had a pronounced effect in delaying fruit abscission on the variety McIntosh as indicated from this study. This effect persists for about 10 days when one application at a .001 per cent concentration is used.

The value of naphthalene acetic acid and certain commercial compounds containing plant growth ingredients as preharvest sprays on Greenings and Baldwins is questionable on the basis of this study.

The unsprayed Greenings held their fruit satisfactorily until October 1, whereas the sprays on Baldwins, although applied late in the season, were of no apparent value in delaying fruit abscission.

It is apparent that varieties respond differently to these sprays, and further studies pertaining to temperature and nature of abscission may reveal the causes of these differences.

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The Influence of Leaf-Fruit Ratio on Alternate Bearing in the Apple[1]

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MUCH emphasis has been placed on the importance of a high leaf-fruit ratio to annual bearing (1, 5, 6). The results of many investigators, however, did not seem to support this view (2, 4, 8). It would be desirable, therefore, to have some further information as to the influence of leaf-fruit ratio on alternate bearing.

Materials and Methods

Four varieties of apples were used in these experiments, McIntosh, Red Delicious, Golden Delicious and Wealthy. All the work was done in the Cornell University Experimental Orchards at Ithaca, New York. The McIntosh, Red Delicious and Golden Delicious used were young bearing trees and the Wealthy were mature bearing trees. Nitrogen was applied annually either in the form of nitrate of soda or in the form of cyanamide in all of the orchards. Most of the trees were moderate to vigorous in growth.

Thinning experiments were carried out in two successive seasons, 1938 and 1939. Beginning June, 1938, bearing limbs on all sides of the tree were ringed at a point where they were one inch in diameter. A strip of about ¼ inch of bark was removed. Immediately after the limb was ringed, the fruits on that part of the limb above the ring were thinned to 20 in number in all cases. The leaf area on that particular part was later calculated and expressed in terms of square centimeters. The percentage of blossoming spurs was calculated by comparing the total number of blossoming spurs to the total number of spurs. This was used to indicate the percentage of fruit bud differentiation.

In the summer of 1939, the same branches which had been used last season were employed for the experiment. Only a few very weak limbs failed to heal over the rings made the previous year. Various limbs were subjected to any of the following four treatments: (a) ringed and thinned, (b) ringed, not thinned, (c) not ringed, thinned, and (d) not ringed, not thinned (check). Thinning was done in the same manner as was done the previous year, leaving 20 fruits on the limb in all cases. The new ring was made from ¾ to ½ inch above the old one.

In both seasons, thinning was done in two periods. The first period was from June 13 to June 30 (38 to 55 days after full bloom), the second period from July 1 to July 17 (56 to 70 days after full bloom). The limbs were so arranged that on each tree, some limbs were thinned during the first period and some others thinned during the second period.

Results of 1938–1939

The coefficients of correlation between leaf-fruit ratio and fruit bud differentiation are presented in Table I. With McIntosh, considering

[1]The writer wishes to acknowledge his deep indebtedness to Professor A. J. Heinicke, who gave invaluable advice and encouragement during the course of the investigations.

TABLE I—Coefficients of Correlation Between Leaf-Fruit Ratio and Fruit Bud Differentiation

	Number of Observations	Coefficient of Correlation (r)	Least Significant Value of r	Highly Significant Value of r	Value of r for Odds 9:1
		McIntosh			
Entire population..	180	0.473	0.138	0.181	—
Leaf-fruit ratio					
200– 699.9.....	95	0.484	0.205	0.267	0.173
700–1399.9.....	85	0.418	0.217	0.283	0.183
700– 999.9.....	72	0.697	0.232	0.302	0.195
1000–1399.9.....	13	0.485	0.553	0.684	0.476
		Red Delicious			
Entire population..	101	0.685	0.195	0.254	0.164
Leaf-fruit ratio					
200– 699.9.....	70	0.181	0.232	0.302	0.195
700–1499.9.....	31	0.534	0.355	0.456	0.296
900–1499.9.....	9	0.609	0.666	0.798	0.582
		Golden Delicious			
Entire population..	88	0.593	0.205	0.267	0.173
Leaf-fruit ratio					
200– 699.9.....	52	0.250	0.273	0.354	0.231
700–1399.9.....	36	0.696	0.325	0.418	0.275
900–1399.9.....	9	0.734	0.666	0.798	0.582

the entire population of 180 limbs, it can be seen that there is a highly significant correlation between leaf-fruit ratio and fruit bud differentiation. The number of spurs differentiating fruit buds increases with the increase of leaf area per fruit. The increase of the former, however, is not directly proportional to that of the latter. Thus, when the leaf area increases from 200 to 699.9 square centimeters per fruit, the coefficient of correlation between these factors is .484. With a still larger leaf area per fruit from 700 to 1399.9 square centimeters, there occurs a decrease in the value of the coefficient of correlation although its level of significance is well above 99: 1. This seems to indicate that somewhere between 700 square centimeters and 1399.9 square centimeters of leaf area per fruit, there is more or less a limit beyond which further increase in leaf area does not result in more fruit bud differentiation.

In order to find this limit, the limbs included between 700 and 1399.9 square centimeters are divided into two parts, one having 700 to 999.9 square centimeters of leaf area per fruit, another having 1000 to 1399.9 square centimeters of leaf area per fruit. The data indicate that while an increase of leaf area from 700 to 999.9 square centimeters per fruit significantly increases the number of spurs differentiating fruit buds, a larger leaf area per fruit of more than 1000 square centimeters apparently has very little effect. Likewise, it is to be noted that the coefficient of correlation in the case of 700 to 999.9 square centimeters of leaf area per fruit is rather high, higher than that of 200 to 699.9 square centimeters. This may possibly be interpreted on the basis that notwithstanding an increase of leaf area from 200 square centimeters to 699.9 square centimeters, a considerable portion of this

range is still below the minimum leaf area required for fruit bud differentiation.

While a highly significant correlation exists between fruit bud differentiation and an increase in leaf-fruit ratio from 200 to 699.9 square centimeters with McIntosh, such a correlation is not significant in the case of Red Delicious and has a level of significance only slightly above 9 : 1 in the case of Golden Delicious which can not be considered as significant. This seems to indicate that Red Delicious and Golden Delicious require a higher minimum leaf area per fruit than McIntosh to differentiate fruit buds. In other respects, the response of Red Delicious and Golden Delicious to the increase in leaf area is essentially similar to that of McIntosh in that with all of the three varieties, there appears to be a range of leaf area, within which, increase in leaf area per fruit causes an increase in fruit bud formation. Outside of this range, either beyond or below, fruit bud differentiation was little influenced by the increase of leaf-fruit ratio.

The variety Wealthy apparently was not influenced by thinning under the condition of this experiment. Thinning was started on June 28 which was probably too late for such a strongly alternate variety.

The data in Table II show the relationship between the time of thinning and fruit bud differentiation. Previous discussion has brought

TABLE II—Coefficients of Correlation Between Time of Thinning and Fruit Bud Differentiation

	Number of Observations	Coefficient of Correlation (r)	Least Significant Value of r	Highly Significant Value of r	Value of r for Odds 9:1
McIntosh					
A. Leaf-fruit ratio between 600 and 899.9 only, entire season..	103	−0.791	0.195	0.254	——
B. Entire range of leaf-fruit ratio:					
June 13 to June 20	81	−0.692	0.217	0.283	0.183
June 20 to July 17	99	−0.526	0.195	0.254	0.164
June 21 to June 30	35	−0.789	0.325	0.418	0.275
July 1 to July 10	64	−0.638	0.250	0.325	0.211
July 11 to July 17	12	−0.097	0.576	0.708	0.497
Red Delicious					
A. Leaf-fruit ratio between 600 and 899.9 only, entire season..	36	−0.645	0.325	0.418	0.275
B. Entire range of leaf-fruit ratio:					
June 13 to June 15	26	−0.879	0.388	0.496	0.323
June 15 to July 17	75	−0.696	0.232	0.302	0.195
June 13 to June 20	52	−0.753	0.273	0.354	0.231
June 21 to July 17	49	−0.183	0.288	0.372	0.243
Golden Delicious					
A. Leaf-fruit ratio between 600 and 899.9 only, entire season..	44	−0.511	0.304	0.393	0.257
B. Entire range of leaf-fruit ratio:					
June 21 to June 26	40	−0.811	0.304	0.393	0.257
June 27 to July 17	48	−0.423	0.288	0.372	0.243
July 10 to July 17	30	−0.126	0.361	0.463	0.296

out the point that within a certain range, different for different variety, fruit bud formation increases with the increase in leaf area per fruit. In an attempt to eliminate this factor of leaf-fruit ratio, only limbs with leaf-fruit ratio between 600 and 899.9 square centimeters were used to study the effect of earliness of thinning on fruit bud formation. From part A in Table II, it can be seen that all three varieties show a significant correlation between these two factors. The correlation is negative which indicates that as thinning is performed progressively later in the season, it is less and less effective in increasing fruit bud formation.

Just how late thinning can be done to be effective in increasing fruit bud differentiation is a question of practical importance. Part B in Table II endeavors to throw some light on this problem. In general, the data show that as late as July 10, about 2 months after full bloom, thinning significantly increased the percentage of fruit bud differentiation. After July 10, however, thinning does not have any effect in promoting fruit bud differentiation as is shown by the very low correlation coefficient. This is in accordance with what Magness *et al.* (7) recommended for Middle Atlantic conditions.

Results of 1939–1940

Of the many factors influencing fruit bud differentiation, there are four which can be studied by means of the data obtained in 1939–1940. These are, heaviness of bloom, yield, leaf-fruit ratio and earliness of thinning. In order to study the correlation between fruit bud formation and either one of these four factors with the effect of the variation of the other factors eliminated, partial correlation between any two of these five variables was calculated.

From Table III, it can be seen that with McIntosh, under the treatment of ringed and thinned, the correlation between fruit bud differentiation and leaf-fruit ratio is not significant. This holds true from gross coefficient through to the third order coefficient when the effects of the other three variables, namely, percentage of blossoming spurs in 1939, yield in 1939, and earliness of thinning, are held constant. A highly significant correlation exists between fruit bud differentiation and the percentage of blossoming spurs in 1939. The relationship is an inverse one, that is, the heavier the bloom in 1939, the smaller is the percentage of spurs differentiating fruit buds during that season, and consequently blooming the following season. There is a similar high correlation between fruit bud differentiation and yield; but the correlation with earliness of thinning is not so significant, the level of significance being slightly above 19:1 only in cases when the effect of the percentage of blossoming spurs in 1939 is eliminated.

Similar calculations with Red Delicious and Golden Delicious brought out the fact that contrary to the findings in 1938, fruit bud differentiation did not seem to be much influenced by leaf-fruit ratio and earliness of thinning. As a whole, the heaviness of blossoming in the spring has a decidedly greater influence on fruit bud formation than any other factors.

TABLE III—FRUIT BUD DIFFERENTIATION ON BRANCHES RINGED AND THINNED, AS SHOWN BY CORRELATIONS BETWEEN (A) LEAF-FRUIT RATIO, 1939, (B) PERCENTAGE OF BLOSSOMING SPURS, 1940, (C) PERCENTAGE OF BLOSSOMING SPURS, 1939, (D) YIELD, 1939, AND (E) EARLINESS OF RINGING AND THINNING, 1939

	0 Order Sub-script*	0 Order Coeff.	1st Order Sub-script*	1st Order Coeff.	2nd Order Sub-script*	2nd Order Coeff.	3rd Order Sub-script*	3rd Order Coeff.
				McIntosh				
Group A	12	−0.010	12.3	−0.139	12.34	−0.192	12.345	−0.201
			12.4	0.003	12.35	−0.144		
			12.5	−0.001	12.45	0.001		
Group B	23	−0.515	23.1	−0.529	23.14	−0.697	23.145	−0.756
			23.4	−0.683	23.15	−0.629		
			23.5	−0.619	23.45	−0.740		
Group C	24	−0.402	24.1	−0.402	24.13	−0.634	24.135	−0.633
			24.3	−0.625	24.15	−0.394		
			24.5	−0.394	24.35	−0.623		
Group D	25	−0.088	25.1	−0.087	25.13	−0.410	25.134	−0.408
			25.3	−0.408	25.14	0.008		
			25.4	0.017	25.34	−0.403		
				Level of Significance				
DF		28		27		26		25
99:1		0.463		0.470		0.478		0.487
19:1		0.361		0.367		0.374		0.381
9:1		0.296		0.323		0.323		0.323

*Subscript 12 denotes correlation between items 1 and 2; 12.3 between 1 and 2 with 3 constant; 12.34 between 1 and 2 with 3 and 4 constant; 12.345 between 1 and 2 with 3, 4, and 5 constant.

$$r_{12.3} = \frac{r_{12} - (r_{13} \times r_{23})}{\sqrt{1-r^2_{13}}\sqrt{1-r^2_{23}}}; \quad r_{12.34} = \frac{r_{12.3} - (r_{14.3} \times r_{24.3})}{\sqrt{1-r^2_{14.3}}\sqrt{1-r^2_{24.3}}};$$

$$r_{12.345} = \frac{r_{12.34} - (r_{15.34}) \times (r_{25.34})}{\sqrt{1-r^2_{15.34}}\sqrt{1-r^2_{25.34}}}$$

DISCUSSION AND CONCLUSION

The results obtained in 1938–1939 showed that within a certain range, different for different variety, there was an increase in fruit bud differentiation with an increasing leaf-fruit ratio. The evidence semed to indicate that there was a relationship between the minimum leaf-fruit ratio required for fruit bud differentiation and the tendency of the variety to alternate bearing. Those varieties which require a higher level of leaf-fruit ratio are more strongly biennial in habit than those which require a lower level of leaf-fruit ratio.

Contrary to the findings in 1938, fruit bud differentiation did not seem to be much influenced by leaf-fruit ratio and earliness of thinning in the experiment conducted during 1939 and 1940. It is to be remembered that the limbs used in 1939 were the same ones used in 1938. Many limbs were ringed twice. Although most of the rings were healed over, or at least partly so, it seems doubtful that the chemical composition of the ringed branches was comparable to those not ringed. As Curtis (3) has shown, ringing not only increases the carbohydrates content, but also tends to decrease the concentration of the mineral

elements in the portion above the ring. It would be reasonable to suppose, therefore, that possibly nitrogen is deficient in the ringed branches in 1939. This supposition is given some weight by examining the result with the treatment not ringed and thinned. It is only in this treatment that the leaf-fruit ratio assumes some importance in influencing fruit bud formation. It indicates that when the branches are not ringed for the second time, the limbs may have a sufficiently high level of nitrogen content to respond positively to the increased leaf area. The deficiency of nitrogen in the tissues of the branches can be further enhanced by the development of a heavy bloom since the developing flowers, among other things, utilize a considerable amount of nitrogen. The heavier the bloom, the more nitrogen is consumed. This probably accounts for the fact that the heaviness of bloom had a decidedly greater influence on fruit bud formation than any other factors in the 1939–1940 experiment.

Another possible explanation can be ascribed to the exceedingly dry season of 1939 at Ithaca. This was one of the driest on record, and a serious moisture deficiency at the time of fruit bud differentiation may be responsible for the discrepancy between the two season's results.

In light of the data herein presented, it is concluded that the leaf-fruit ratio, which is chiefly concerned with carbohydrates supply, is not always the deciding factor for fruit bud differentiation. Undoubtedly, alternate bearing is influenced by a number of factors, and it would be absurd to attach too much importance to any one single factor. Under certain conditions, the nitrogen supply or water supply or some substance not yet known might have more influence on alternate bearing than any other factors.

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Relative Carbohydrate and Nitrogen Concentration in New Tissues Produced on Ringed Branches[1]

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THAT it is possible to increase the set and size of apples and other fruits by ringing the branches is now well established (6, 7, 8, 2). The mechanism of this effect is not yet clear, however, though there is some evidence that this treatment may have a favorable influence on the nutrition of the bearing spurs or twigs (2).

Since the nitrogenous and carbohydrate substances seem to be the chief organic materials that build the fruit, it was thought desirable to determine their relative concentration in the new tissues developed on ringed and control branches. The apple spur system was selected as a convenient unit because of its close association with fruit production.

An ample number of spurs from ringed and control branches of the Rome (ringed on April 14 and 30) and Ingram (ringed on April 19) varieties were collected early in the morning on the following dates: *Rome,* April 14, flowers opening; April 30, beginning of the second drop; May 14, third drop in progress; May 24, all drops completed. *Ingram:* April 19, full bloom; May 14, third drop beginning; May 26, last drop not quite completed. Bearing spurs only were taken into consideration. The material was divided into flowers or fruit, leaves, current season's growth (cluster base and side bud or vegetative shoot) and old portion of the spur. Preservation and chemical analyses were performed according to standard procedures developed in our laboratory. A part of the results are presented here in graphical form (Figs. 1, 2, and 3).

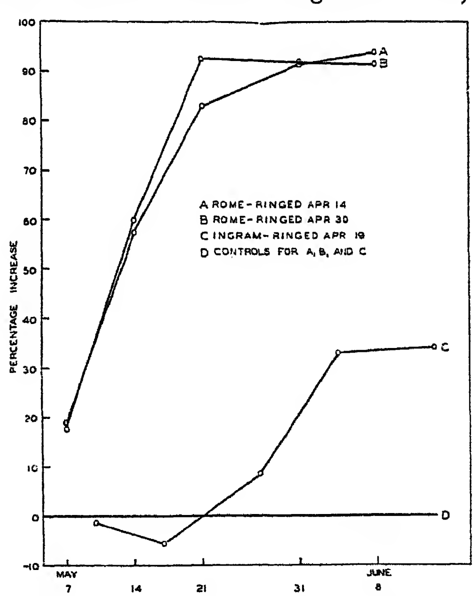

Fig. 1. Effects of branch ringing on fruit set of the Rome and Ingram varieties.

It will be observed from Fig. 1 that increase in fruit setting of the Rome variety was very closely the same whether ringing was performed on April 14, when flowering was just beginning (line A), or 16 days later (line B). This would seem to indicate that the treatment had a beneficial effect chiefly on the second and/or third drops (5). Results obtained

[1]Contribution from the Department of Horticulture, Missouri Agricultural Experiment Station Journal Series No. 715.

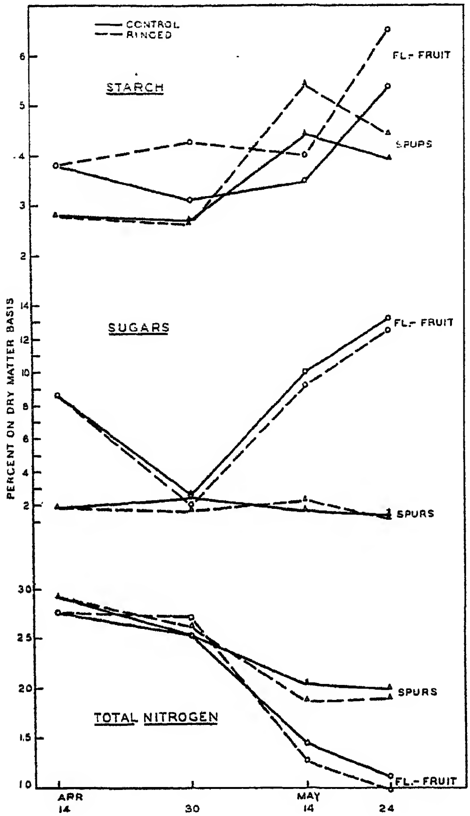

FIG. 2. Relative carbohydrate and nitrogen content of flowers or fruit and new portions of the spur of ringed and control branches. Variety Rome, ringed April 14.

with Ingram lend support to this probability, for in this case the fruit set was not increased until the period of the third drop (line C). The fourth drop in either variety may not have been influenced to any extent, for in all three instances (lines A, B and C), the curves referring to this period show protracted plateaus. What possible physiological changes may have occurred in the terminal parts, especially the spurs, of the ringed branches, which has caused or accompanied this effect?

The comparative concentrations of starch, sugars and nitrogen in the flowers or fruit and the current season's growth of the spurs (cluster base and other vegetative parts, exclusive of leaves) of ringed and control branches of both early and late ringed Rome trees are presented in Figs. 2 and 3. Similar results were obtained with the Ingram variety, but are not given here. In general, all show the usual seasonal changes in these substances (4). Because of the treatment, however, both the fruit and the spurs were higher in carbohydrate and somewhat lower in nitrogen content, which is in general agreement with Greene's results (2). In the case of the late ringed Romes, this difference was small or non-existent, yet fruit setting was augmented just as much from late as from early ringing (Fig. 1). Records of chemical analyses of newly formed shoots and of leaves (not presented here) showed a similar trend, thus indicating that the treatment was conducive to the accumulation of organic food materials at all terminal points of the branch. This condition was obtaining despite the fact that these substances undoubtedly were utilized in greater quantity because of the increased fruit production and possibly also more extensive shoot growth (6).

Discussion and Conclusions

The above evidence, that of others (4, 2), and some still unpublished data would seem to indicate that carbohydrate accumulation is associated with the growth and development of the apple from a period when the second and third drops usually occur till the time of fruit maturity. It is well known, of course, that the final size of the fruit is determined largely by the carbohydrate supply (leaf-fruit ratio). Consequently, it should be quite natural that a treatment like branch ringing, which results in holding above the ring for a certain period the carbohydrates moved up from reserves early in the spring, and those subsequently synthesized by the newly formed leaves, would benefit the fruit crop. Branch ringing or scoring, therefore, may be considered an orchard practice that permits us to regulate to a considerable extent the number of fruits set and their size at a stage when nitrogen fertilizers may not be so effective, for it is here a matter of carbohydrate supply.

During the early phases, immediately after flower pollination and fertilization, however, fruit setting and development are very much influenced by the nitrogen supply. The apple flowers are formed and the fruit is initiated at the time when the shoots and leaves also start growing. Both the reproductive and the vegetative organs require large quantities of nitrogen for the first stages of development (4). The detrimental effects of too severe a competition for this element may be alleviated by the popular practice of applying nitrogen fertilizers in the spring or preceding fall.

The question may be raised whether fruit setting after all is directly correlated with or controlled by the food supply to the reproductive organs and associated tissues. It is possible that "growth substances" (hormones) of some type may be the real regulatory agents, while nitrogen, carbohydrates, and other food materials may merely serve as sub-

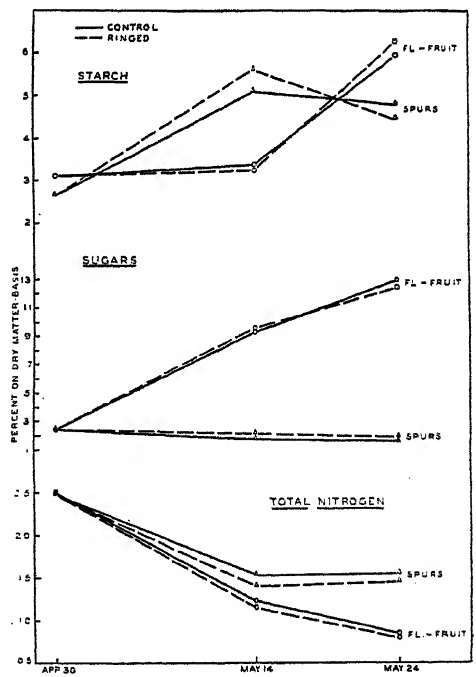

Fig. 3. Relative carbohydrate and nitrogen content of flowers or fruit and new portions of the spur of ringed and control branches. Variety Rome, ringed April 30.

strates for these catalysts. It has been demonstrated that "growth hormones" (using this term in a generic sense) are produced by the terminal buds and new shoots of the apple and that the peak in their formation (concentration) is reached prior to the time of most active growth (1). This is likewise the crucial period of fruit setting and the occurrence of the largest number of drops (5). Since these growth substances move basipetally from the current season's growth to older portions of the tree, it is more than probable that branch ringing may cause their retention above the ring and thereby increase the general concentration from this point up. It has been found that growth hormones are produced in greater quantity by reproductive than by vegetative shoots (1), that they are present in relatively large amounts in the ovules and developing seeds, and that certain of these substances are very effective stimulants for fruit formation (parthenocarpically) (3). This information is very suggestive of their possible importance in fruit production.

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Studies on Time of Peach Thinning from Blossoming to Maturity

By J. H. WEINBERGER, *U. S. Horticultural Field Laboratory, Fort Valley, Ga.*

IN the last few years the practice of thinning early-ripening varieties of peaches in the bloom has gained in popularity among peach growers in the important peach-producing area around Fort Valley, Georgia. Three reasons may be responsible for this shift in time of thinning: first, the apparent benefits from early thinning; second, the large proportion of early-ripening varieties grown in this area; and third, the difficulty of obtaining sufficient labor to thin large plantings later in the season.

Numerous experiments (1, 2, 3, 4) have been reported on the subject of thinning, but there is little experimental evidence, especially with early-ripening varieties, showing the comparative effects of thinning in the bloom and during the succeeding six weeks. Tukey and Einset (5) report increases in size and color of fruit and flower bud formation with Elberta when bloom thinned, as compared with later thinnings.

In the present study, covering a 3-year period, fruit on different plots were thinned at regular intervals of approximately 2 weeks beginning at full bloom, to determine at which period in the growth of the fruit the thinning was most effective. The early-ripening varieties Early Rose, Early Hiley, and Hiley, all located in commercial orchards near Fort Valley, were used. From six to 10 trees were included in each plot, and except for the Hiley variety, these plots were duplicated for each date of thinning. The original plan had been to use the same trees and treatments in successive years, but a light set of fruit the second season eliminated the advantages of that plan and made it advisable to shift to younger plantings the third season. Thus, 8-year-old Early Rose trees were used in 1938 and 1939, and 5-year-old trees in 1940. Ten-year-old Hiley trees were used in 1938 and 4-year-old Early Hiley trees in 1940.

In these studies it was desired to have the fruit on all plots spaced as near as possible to 6-inch intervals at harvest. To accomplish this, it was necessary to vary the thinning distance on various dates to compensate for the natural abscission of fruit which followed the earlier thinnings. Thus at bloom thinning the blossoms were left 3 inches apart; at the later thinnings 4; then 5; and finally, after the May drop, 6-inch spacings were used. By actual count in 1938 from 75 to 80 per cent of Early Rose flowers were removed in blossom thinning. The drop on thinned trees was very light in comparison with that of unthinned trees, but could not be ignored if the various plots were to have comparable loads of fruit. At harvest all the fruit from each plot was run over a grader and sorted into classes varying by ¼-inch.

Results

Early Rose Variety:—The effect of time of thinning on Early Rose peaches is shown in Table I. In 1938 the percentage of the total yield (on weight basis) in the two larger grades, is greatest for blossom thinning and steadily decreases through later dates of thinning. Conversely, trees thinned later in the season have a greater proportion of their yield in the smaller sizes. Yield of the blossom-thinned trees was lower than in other plots, because of an unexpectedly heavy drop after thinning; nevertheless they bore 45 pounds of fruit over 2 inches in diameter, compared with but 16 pounds from trees thinned May 2.

In 1939 there was an unusually heavy drop of Early Rose fruit during the season. The average yield (Table I) was only one-half that of the previous year. As a result, time of thinning had little effect on the size of the fruit at harvest. It was noted that the early-thinned trees which had had from one-third to one-half of the crop removed in thinning nevertheless carried more fruit to maturity than the later-thinned trees, as shown by average yield.

TABLE I—Effect of Time of Thinning on Size of Early Rose, Hiley, and Early Hiley Peaches

Time Thinned	Number of Trees	Percentages of Crop in Size Classes: Under 1¾ Inches	1¾ to 2 Inches	2 to 2¼ Inches	Over 2¼ Inches	Yield Per Tree (Pounds)
		Early Rose, 1938 Season, Harvested May 23 to June 2				
Mar 9 (full bloom)	20	2.2	37.6	54.1	6.1	75
Mar 28 (shucks off)	17	3.5	50.2	44.9	1.4	99
Apr 12 (before May drop)	17	4.8	66.1	28.8	0.3	116
Apr 22 (pits hardening)	17	6.2	70.2	23.8	0.3	104
May 2 (pits hard)	20	11.7	74.5	13.5	0.3	120
		Early Rose, 1939 Season, Harvested June 5 to 12				
Mar 24 (full bloom)	20	1.8	16.0	56.1	26.1	45
Apr 12 (shucks off)	17	2.5	22.6	56.3	18.6	51
Apr 26 (before May drop)	17	1.1	18.2	58.6	22.1	47
May 11 (May drop)	17	1.5	16.8	55.8	25.9	29
May 24 (pits hard)	20	1.8	18.7	55.1	24.4	35
		Early Rose, 1940 Season, Harvested June 15 to 22				
Apr 1 (full bloom)	16	9.8	46.7	40.4	3.1	120
Apr 16 (shucks off)	17	7.8	49.0	41.0	2.2	114
May 2 (before May drop)	18	16.2	62.7	20.9	0.2	95
May 16 (pits hardening)	15	23.9	63.5	12.6	0.0	110
Unthinned	8	79.1	19.8	1.1	0.0	127
		Hiley, 1938 Season, Harvested June 11 to 17				
Mar 9 (full bloom)	10	0.5	12.1	65.5	21.9	122
Mar 30 (shucks off)	9	0.9	24.0	67.1	8.0	145
Apr 12 (before May drop)	10	1.2	27.1	60.8	10.9	130
Apr 22 (pits hardening)	9	1.3	28.9	67.0	2.8	126
May 6 (pits hard)	15	1.9	32.5	59.8	5.8	125
May 21 (final swell)	10	0.6	29.4	62.3	7.7	133
Unthinned	6	6.2	65.0	27.5	1.3	162
		Early Hiley, 1940 Season, Harvested June 28 to July 8				
Mar 25 (full bloom)	20	1.2	17.4	61.1	20.3	112
Apr 10 (shucks split)	20	1.5	21.5	62.9	14.1	102
Apr 25 (before May drop)	20	1.1	23.1	64.3	11.5	114
May 10 (May drop)	20	1.0	27.0	65.2	6.8	85
May 26 (pits hard)	8	2.2	31.2	60.1	6.5	97
Unthinned	10	9.4	67.3	23.2	0.1	143

Early Rose trees in 1940 set a heavy crop of fruit, and again the effects of early thinning on increased size of fruit are evident (Table I). Thinning in bloom resulted in 43 per cent of the crop being above 2 inches in diameter, while thinning a month before harvest, May 16, gave only 12 per cent over 2 inches. Also the percentage of fruit under 1¾ inches increased with the later thinnings from 10 per cent for blossom thinning to 24 per cent for the latest thinning. Although thinning a month before harvest was not nearly as effective as earlier thinning, it was much superior to no thinning. Much of this gain was due to the removal of small and injured peaches by thinning, which tended to increase the size average of the remaining fruits. On unthinned trees only 21 per cent of the fruit graded above 1¾ inches; 23 per cent was below 1½ inches in diameter, and was useless for marketing.

Hiley Variety:—With Hiley in 1938 (Table I), peaches from trees thinned in the bloom were also the largest. The percentage of fruit in the larger-sized classes decreased progressively with later thinning, and the percentage in the smaller sizes increased from 13 to 30. Again, late thinning 3 weeks before harvest resulted in a surprisingly large increase in the size of fruits over unthinned peaches.

Early Hiley Variety:—Early Hiley in 1940 (Table I) responded similarly to early thinning. Blossom-thinned trees (March 25) had 20 per cent of the fruit over 2¼ inches at harvest, while late-thinned trees (May 26) had only 6 per cent in that group. Likewise the proportion of smaller-sized peaches, under 2 inches, increased from 19 per cent for earliest thinning to 33 per cent for latest thinning. Thinning at three different intervals between these extremes resulted in fruit of intermediate size in accordance with the date of thinning. Also, thinning a month before harvest increased the size of the fruit markedly, at the same time reducing the total yield about 30 per cent.

With these early-ripening varieties it is evident that the earlier the trees were thinned, the greater was the percentage of fruit in the larger sizes at harvest. A delay of only 2 weeks in time of thinning at any period after full bloom resulted in smaller-sized fruits. Apparently the earlier the competition between fruits for available food material was relieved, the more advantage the remaining fruits possessed.

The earlier the thinning was done the more time was required to thin a tree. When thinned in bloom it took one man 112 minutes to thin an 8-year-old Early Rose tree; 2 weeks later 56 minutes were required; and at later intervals, 30 minutes and 24 minutes. The time required to thin a 4-year-old Early Hiley tree varied from 81 minutes in the bloom to 48, 30, 18, and 13 minutes at successive later dates. In the late thinnings one-third to one-half of the peaches were removed. In commercial practice no attempt is made to space flowers when thinning in the bloom, as was done in this experiment, and the time required to blossom thin a tree approximates that required in late thinning. To perform a careful job of thinning, however, the time required was roughly in line with the number of fruits or flowers to be removed.

With Early Rose and Hiley varieties in 1938, trees that were

thinned early matured their fruit earlier and a greater portion of the crop was harvested in the first pickings. In the other experiments time of thinning did not affect time of ripening appreciably, except to hasten maturity in comparison with unthinned trees. Also thinning did not increase the set of flower buds on Early Hiley trees in 1940 or Early Rose trees in 1939.

Several factors must be considered in deciding when is the best time for thinning early-ripening varieties of peaches. From a practical standpoint it was impossible to effect a complete thinning job at blossoming time. As a precautionary measure in these experiments, more flowers were left on the trees than the number considered necessary for a normal crop. After danger of frost was past it was necessary to rethin these plots lightly to equalize the set with that on the other plots. This procedure, of course, did not tend to make blossom thinning more effective. However, in two of the five experiments a natural drop thinned the trees beyond the desired spacing (Early Rose in 1938 and 1939).

Thinning 2 weeks after bloom, when the shucks had split, was still too early for a complete thinning job, and a light rethinning on a few trees was necessary.

Thinning could be completed in one operation a month after bloom, but less time was required at the 6-week interval. At the latter time the "May" drop had not occurred, but peaches destined to drop were smaller than others. Also those fruits that were larger because of favored position on the branch could be selected and allowed to remain in thinning. Pits had not yet started to harden, and some benefit in increased size of endocarp could be expected from thinning at this time.

It would seem, therefore, that with early varieties under Georgia conditions, it is desirable to thin as early in the season as practicable. While thinning in the bloom is advantageous, especially where a heavy set of fruit is in prospect, the hazards involved cannot be overlooked. A light blossom thinning, supplemented by another thinning 6 weeks later, would probably be the more successful under average conditions.

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Simple and Complex Periclinal Tetraploidy in Peaches Induced by Colchicine

By HAIG DERMEN, *U. S. Horticultural Station, Beltsville, Md.*

TETRAPLOID tissues have developed in peach following treatment of newly germinated seed with colchicine solution. Enlarged stomata indicate that the epidermal tissue is polyploid, but are not an indication of chromosome constitution of underlying tissues. Enlarged pollen grains indicate that the tissue from which they are developed is polyploid. Transverse paraffin sections from the very tips of growing stems have shown the chromosome pattern in trees examined. In one case the epidermis only is tetraploid, the inner tissues remaining diploid. In a second plant, one side shows tetraploidy of the whole epidermis and of all the cortex except a small area adjacent to the stele. The stele and pith are diploid except for one small area. The other side of the same plant has diploid epidermis, but all inner tissues are tetraploid. Pollen and egg cells produced from that side of the plant should be diploid, barring irregularities during meiosis. Cytological examination of such treated material is necessary before the true chromosomal condition can be determined.

Chromosome Number of the Beach Plum (Prunus maritima)

By W. D. WEEKS, *Massachusetts State College, Amherst, Mass.*

THE beach plum, *Prunus maritima,* is a rather low straggling bush which grows to a height of 3 to 12 feet. It grows rather extensively in sandy soil on the Cape Cod section of Massachusetts. The natives of this section gather the fruit from the wild bushes for making jelly. Very little has been done in the way of trying to improve the fruit, either by selection or breeding, although it appears to have possibilities.

The chromosome count was determined from root tips of seedlings which were growing in pots in the greenhouse. Active growing root tips were taken and immediately placed in CRAF fixing solution, a vacuum being used to hasten fixing. After the material had remained in the fixing solution overnight, it was run through the alcohol chloroform series and imbedded in paraffin. Cross sections 12 microns thick were cut, mounted on slides, and stained with Heidenhain's haematoxylin or crystal violet.

The slides were examined at magnifications of 697.5 and 1162.5. Sixteen somatic chromosomes were found showing that the 2n number of *Prunus maritima* is the same as that of *P. Americana* and *P. salicina.* The establishment of the chromosome number of 16 for the beach plum should give some indication as to its use for future breeding work with other species of Prunus. It is more likely that the beach plum can be successfully crossed with species of Prunus such as Americana and salicina, which have 16 for their 2n chromosome number, than with species like domestica and insititia which have 48 for their 2n number.

Pollination Experiments With Starking

By Gordon G. Brown and Leroy Childs, *Oregon Experiment Station, Hood River, Ore.*

STARKING and Striped Delicious, when planted solidly in large blocks without pollen varieties, are usually unfruitful or subject to low yields, particularly during seasons unfavorable to cross pollination. Owing to the prominent commercial importance of the Starking in the Hood River Valley, experiments were conducted in 1940 to determine varieties, particularly the promising new red strains, with which it may be successfully crossed.

Pollination tests were conducted in orchard No. 1, elevation 400 feet and in orchard No. 2, elevation 1,500 feet. Cuttings with bloom for orchard No. 1, were taken from trees on April 13, and immediately placed at room temperatures to accelerate their development. Pollen was removed on April 15 and 16, and held in shaded petri dishes until applied to Starking in full bloom on April 17. Branches under test were covered with cheese cloth during periods when cross pollination from external agencies, such as bees and other insects, was possible. Pollen in both experiments was applied by hand with a camel's-hair brush.

Weather conditions immediately prior to and after the opening of bloom with orchard No. 1, were especially favorable. The period was marked by warm temperatures with clear or partly cloudy skies. Maximum temperatures varied from 65 to 70 degrees F and minimum from 34 to 50 degrees F. The number of blossom clusters setting one or more apples each, was determined on June 4 after the "June drop".

The procedure followed with orchard No. 2 was similar to that of orchard No. 1 in the collection of bloom, extraction and storage of pollen. Pollen of Red Spitzenberg (Goodenough strain), Blaxtayman and Staymared, was applied to Starking on May 2, due to advanced maturity of pollen taken from a similar elevation as that of orchard No. 1. With the remaining varieties, this operation was performed

TABLE I—Percentage of Starking Delicious Blossom Clusters Setting One or More Apples Each Following Cross Pollination (1940 Results)

Pollen Variety	Orchard No. 1		Orchard No. 2		Per Cent Pollen Germination
	Per Cent	No. of Apples Per Cluster	Per Cent	No. of Apples Per Cluster	
Spitzenberg (Goodenough Red strain)	28.9	1.0	26.09	1.16	75
Blaxtayman	—	—	0	0	5
Staymared	7.7	1.25	1.7	1	10
Blackjon	63.8	1.56	46.9	1	71
Ortley	—	—	22.7	1	68
Golden Delicious	22.2	1.66	39.5	1	48
Newtown	39.8	1.74	36.4	1	41
Blackmack	97.0	1.84	28.07	1	57
Gravenstein (Red strain)	2.8	1.0	—	—	—
Winter Banana	11.5	1.0	—	—	—
Starking	1.05	.33	1.64	1	66

on May 6. Delay in application was occasioned by rainfall on May 3, and to tardy development of Starking bloom.

Weather conditions generally were less favorable for blossom development and fruit set for orchard No. 2. Frost injured or killed approximately 10 per cent of the total bloom at the higher elevation with amounts varying in the individual cluster, from none to 3. Injured blossoms were removed before pollen was applied. Owing to slowness with which bloom developed under the cheese cloth bags, and the need for removing those which were injured or dead, the tips of the unseparated petals were cut away to permit inspection and make hand pollination possible.

Germination tests, using a 10 per cent sugar solution for the first three varieties, were performed on April 28, and for the remaining, on May 4. For some unaccountable reason, the entire series of tests conducted in a similar manner on April 18 for orchard No. 1, showed uniformly low germination. Results from the crossing of this pollen with Starking, however, indicate that the material for the most part was good.

Conclusions

Pollination experiments in Hood River Valley during 1940, indicate that Starking was practically self-unfruitful but that a successful set of fruit was obtained when this variety was pollinated by certain other commercial varieties that bloom at approximately the same time. The greatest per cent set was obtained from crosses with Blackmack and Blackjon.

An Acquaintance with Peach Varietal Types is Essential in Peach Breeding to Secure Improved Varieties[1]

By M. A. Blake, *New Jersey Agricultural Experiment Station, New Brunswick, N. J.*

THERE are two main objectives in the breeding of peaches: (a) the securing of improved varieties that will help to solve our ever changing economic problems; and (b) the discovery and proof in a technical manner of fundamental laws which govern the inheritance of plant characters.

Facts can often be established by the survey method in a comparatively short time which require years of effort when limited controlled studies are made. Keen, experienced producers and processors of peaches recognize many qualities and characters and combinations of same which a variety must possess to be satisfactory. These include external characters such as tree size, vigor, form, and strength; flower type, and whether fertile or sterile, fruit size and form, skin color, and flesh color.

Another series of characters may be classed as physiological, which include the degree of fruitfulness. Some varieties set few fruit buds, others set a considerable number, many of which are relatively weak and under-developed at leaf fall. Such varieties are truly weakly fruitful, vegetative types. Other varieties set fruit buds freely, nearly all of which are well-developed by the dormant season. These are truly fruitful types.

Varieties of peaches also vary in their response to temperature, light, aeration, soil moisture, resistance to pests and spray materials. From a consumer's and processor's standpoint the acid, sugar, catechol tannin, and other chemical contents of the fruit of a variety of peach are outstanding characters. These characters are recognized and evaluated in commercial practice by producers, distributors, and consumers. The variety from a grower's standpoint is a complete plant entity including tree, leaf, flower, and fruit characters susceptible or resistant to a wide range of factors.

It is not a difficult matter to learn from the experienced peach growers of some regions what the characters are which they wish combined into a new plant entity. The information is generally given, however, in terms of other varieties; for example, a tree as hardy as Chili, adaptability of tree equal to Elberta, fruit equal to J. H. Hale in appearance and short pubescence, edible quality equal to Fireglow, and resistance to bacterial leaf spot equal to Hiley.

It will probably be a long time before a statistical analysis or the genetics of all of the characters of the peach will be determined and published, but this does not need to hinder progress in practical breeding. A knowledge of how varietal types in fruits, trees, and physiological characters behave in breeding is an efficient basis of procedure.

[1]Journal Series paper of the New Jersey Agricultural Experiment Station, Division of Horticulture.

The Crawford Varietal Type

The Early Crawford has been known since the middle of the 19th century. It probably is a descendant of Alberge, which is several centuries old. Both of these varieties are said to belong to the Persian race. In view of the present knowledge of the origin of the peach it would be more correct to say that they are of the European type.

Varieties such as Early Crawford, Fitzgerald, St. John, Reeves, and Late Crawford are all of the Crawford or Alberge fruit and tree type. They possess certain characteristics in common. It was learned many years ago that the peaches introduced from Europe and their progeny were not satisfactory commercial varieties in the deep South. Price (1) wrote in 1896, "It is almost useless to plant this race in the southern part of the Gulf States".

The fruit of the Crawford or Alberge-type peaches tends to be too small and variable in size on the same tree and to vary from generally small to generally large from season to season regardless of thinning. The skin is relatively thin, and is easily cut or broken when the fruit is mature.

When Early Crawford was selfed at the New Jersey Station its progeny were all of the Crawford-type in both tree and fruit characters. Some trees produced fruit with non-melting flesh similar to Tuskena, but many varietal types possess a character for non-melting flesh.

When Early Crawford was crossed upon Elberta or the reciprocal cross was made, the progeny greatly resembled Early Crawford in such characters of fruit as relatively small size, variableness in size, and tender texture of skin and flesh. Fruits of some of the progeny were more oblique with a more pronounced wing to the pit than the Crawford. The edible quality was also diluted to some degree in this progeny by Elberta, but the dominant fruit characteristics were Crawford.

Many of the Alberge or Crawford-type varieties are rather low in catechol tannin, and the texture, color, and edible quality of the flesh are highly regarded. Nevertheless, very few commercial peach growers in the Atlantic seaboard states will plant Crawford-type peaches if they know a variety to be of such a character.

The J. H. Hale Type

The J. H. Hale peach is characterized by a relatively small to medium sized thick-twigged tree, as it develops upon the Atlantic seaboard. Elberta trees are markedly larger than J. H. Hale, while Salberta, Smock, and Lemon Cling are examples of varieties that are larger even than Elberta.

The J. H. Hale is not adapted to as wide a range of conditions as Elberta. It is not particularly desirable at Fort Valley, Georgia, or in the more northerly districts of the country. It lacks the productiveness, hardiness, and adaptability of Elberta. Certain physiological characters of the variety are evidently the reason. Varieties of the true J. H. Hale tree and fruit type, such as Rio Oso Gem, and Candoka are

likely to respond in a similar manner to J. H. Hale although perhaps not to the same degree. Fruits of the J. H. Hale are medium high in tannin even under the most favorable conditions, and very high in some areas upon the Pacific Coast. A breeder should decide whether he desires a new variety for a given region that will possess the J. H. Hale tree, fruit, and physiological type.

The Greensboro Type

The Greensboro peach is characterized by a rather vigorous, wide-spreading tree that is relatively hardy in a broad sense. It develops many large fruit buds per foot of annual growth under a wide range of soil and fertility conditions. At New Brunswick, New Jersey, the annual bud set is rather consistently 30 to 35 buds per foot. Even under unfavorable environmental conditions the bud set is often 20 buds per foot.

Bud set may be regarded as an external character, but it is also evidence of the presence of physiological characters which enable this plant entity to be a markedly fruitful type.

Cumberland, whose parents were Belle and Greensboro, and Raritan Rose, the result of a cross of J. H. Hale x Cumberland, possess this same character of a heavy bud set under a wide range of environmental conditions. Greensboro has other characters which tend to be dominant in crosses, such as flat-cheeked fruits and rapid softening of flesh particularly at the apex and suture.

The Vegetative Type

In contrast to the Greensboro type, there are varieties upon which fruit bud development proceeds relatively slowly in late summer and early fall every year in a given environment. A proportion of the buds are always weak, particularly upon the most thin and most vegetative twigs. The trees indicate their sensitiveness to factors of their growing environment by variableness in bud development and in relative fruitfulness. Under environmental conditions which favor a large reserve of carbohydrates in the early summer a good set of well-developed fruit buds for the variety commonly results. Such varieties may be rather vegetative, develop a light bud set and be susceptible to winter cold one year and be of a fruitful type with a good bud set and greater hardiness the next year.

However, this type is too uncertain to be widely adaptable. Reeve's Favorite, Chair's Choice, Augbert, Candoka, Berks, Fireglow and Primrose are examples of this type in the environment of New Brunswick, New Jersey. The degree of vegetativeness varies greatly with the variety and the nature of the environment. Augbert is noticeably more vegetative and develops a lighter bud set in northern New Jersey than it does in southern New Jersey.

Some unnamed peach seedlings of Fireglow open-pollinated, and Berks x N. J. 51025 are so vegetative that many of their buds die in late fall and early winter each year before low temperatures actually occur.

Additional Varietal Types in Crosses

Eclipse self-pollinated yielded progeny all of which produced Eclipse-type trees and fruits. Some were freestones; others clings and semi-clings.

All of the progeny of Delicious crossed with J. H. Hale produced white-fleshed peaches. There were some seedlings of the Hiley type and all of these ripened their fruits at about the Hiley season. There were other seedlings which produced fruits of the Belle type and they all ripened their fruits at about the Belle season, or a little later.

A cross of J. H. Hale x 41 S.D. (Slappey x Dewey) yielded progeny which were all of the Crawford or Alberge fruit type.

Progeny of Golden Jubilee open-pollinated were all of the Golden Jubilee fruit type but the time of ripening varied from early until late.

Self-pollinated Belle gave progeny that could be separated into Belle, Hiley and a few other white-fleshed fruit types, and Slappey, Eclipse, and Ambergem in yellow-fleshed fruit types.

New Jersey 113115, a Hiley type from Belle selfed, when crossed with Goldmine Nectarine gave progeny all of which produced Hiley-type fruits.

Types are Numerous

There are many different types of peaches depending upon the factor or factors employed in classification. A keen and earnest plant breeder can soon learn how they are inherited. It is the experience of the author that a knowledge of peach varietal types including tree and fruit such as Alberge or Crawford, Eclipse, Elberta, Greensboro and Hiley peaches and how these types are inherited is more helpful in the breeding of improved varieties of peaches for special regions and uses than is a genetical study of the progenies by statistical methods.

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Tests With New Copper Fungicides With Special Reference to Injury, Tenacity to Foliage, and Dwarfing Effect[1]

By H. T. Hartmann, *University of California, Davis, Calif.*

EFFORTS have recently been made by plant pathologists and fungicide manufacturers to develop materials which would be acceptable as substitutes for Bordeaux Mixture. Consequently several types of relatively insoluble copper-containing spray materials have been introduced during the last few years. The active ingredients are such compounds of copper as oxides, silicates, hydroxides, chlorides, and basic sulfates. These materials are being tested at several Stations to determine their merits as substitutes for Bordeaux.

During the seasons of 1939 and 1940 comparisons were made at the Missouri Agricultural Experiment Station between a number of the new proprietary copper-containing spray materials, Bordeaux Mixture, and lime sulfur. It was desired to derive some indication as to the ability of these new sprays to control fungous diseases, to compare their toxicity to fruit and foliage, and to observe any effect they might have on the size of cherry fruits. The materials were to be further evaluated by testing their tenacity to the leaf surface of the apple and cherry during a period of weathering.

Methods

The 1939 tests were made on apples and cherries at the University Fruit Farm. Two large bearing trees of Golden Delicious and Jonathan apple and three to four mature Montmorency cherry trees were used for each treatment. In 1940 the spraying program was enlarged to include more materials and a wider variety of plots. Spray applications were made to plots consisting of two trees each of Ben Davis and Rome Beauty apple and four to five trees of mature Montmorency cherry trees at the University Fruit Farm. In addition eight plots of 18 trees each were sprayed in a 2-year-old cherry orchard at Monett, Missouri, consisting mainly of the Montmorency variety. Also six plots of seven trees each of large, bearing Montmorency cherry trees were used at Independence, Missouri. In 1939 all the applications were made to the apples as cover sprays on May 17, June 3, June 27, and July 24. In 1940 the sprays were made as cluster bud (April 21), calyx cup (May 9), and first cover (May 23) applications. Four cherry sprays were applied both years, the first application being made at time of bloom when the petals were two-thirds off. Subsequent sprays were applied at 2-week intervals, the last being made immediately following harvesting.

The materials tested, other than Bordeaux Mixture and lime sulfur, are listed below together with the concentration used in pounds per 100 gallons, their principal active ingredient, and the manufacturer:

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[1]This investigation was conducted by the writer at the Department of Horticulture of the Missouri Agricultural Experiment Station.

Basicop (3–100)	Basic copper sulfate	Sherwin Williams Co.
Bordow (4–100)	Cu-Mg complex	Dow Chemical Co.
Coposil (2½–100)	Copper-ammonium silicate	California Spray Chem. Co.
Cupro K (3–100)	Copper oxychloride	Rohm and Haas Co.
Cuprocide 54y (1–100)	Yellow cuprous oxide	Rohm and Haas Co.
Copper Hydro 40 (4–100) and Lime (2–100)	Copper hydroxide	Chipman Chem. Co.
Copper Phosphate (5–100)	Copper phosphate	Monsanto Chem. Co.
Copper Comp. A (2–100) and Lime (3–100)	Copper polychloride	E. I. duPont Co.
Spray Cop (1½–100) and Lime (2–100) and zinc sulfate (½–100)	Basic copper sulfate	General Chem. Co.
Yellow Cuprocide (1½–100)	Yellow cuprous oxide	Rohm and Haas Co.
Z.O. (6–100)	Copper zeolite	Permutit Co.

A 6–8–100 Bordeaux was used and liquid lime sulfur was applied at the rate of 2½–100. Arsenate of lead at the rate of 2–100 was added to all applications.

To evaluate the materials measurements were taken of the effect of the sprays on the leaf area and fruit size of the cherry, the injury to the foliage of the cherry and apple and to the fruit of the apple, control of Cherry leaf spot (*Coccomyces hiemalis*), and the tenacity of the sprays to the foliage of the apple and cherry.

Results

Effect of Sprays on Fruit and Foliage Size:—The data in Table I shows that Bordeaux Mixture had a dwarfing effect on both the fruit and foliage of the cherry under the conditions of the tests. In every experiment the fruit from the Bordeaux sprayed trees was the smallest in size. This agrees with previous evidence that Bordeaux has a dwarfing effect on the fruit of the sour cherry (1, 3). In general, considering all the tests made, the fungicides used exhibited various degrees of dwarfing of both fruit and foliage. In accord with the results of Young (4) a dwarfing of the foliage was obtained with lime sulfur as well as with Bordeaux. Lime sulfur did not result in a reduction in fruit size except in one instance.

These results were obtained one year when there was no cherry leaf spot infection and a second year when it was only light to moderate in amount. Consequently any dwarfing effect can be more definitely ascribed to the spray materials as there was little to no complicating factor of disease injury to the foliage.

TABLE I—THE EFFECT OF SPRAY MATERIALS ON THE SIZE OF CHERRY FRUIT AND FOLIAGE

Spray Material	Fruit: No. of Berries per 500 Gms. (Average of 6 Samples)			Average Leaf Area (sq. cm.) (500 Leaves per Sample)		
	1939	1940		1939	1940	
	University Farm	University Farm	Independence, Mo.	University Farm	Independence, Mo.	Monett, Mo.
Spray Cop	—	144.0	—	—	—	—
Coposil Hydro 40	152.6	147.3	—	19.5	—	—
Check	151.0	152.5	148.8	22.1	18.7	21.0
Z. O.	162.5	—	—	18.6	—	—
Cuprocide 54y	163.1	—	—	22.3	—	—
Lime Sulfur	175.0	149.4	147.0	14.1	15.8	18.9
Cupro K	177.6	144.6	157.3	18.1	14.9	19.8
Yellow Cuprocide	—	150.2	—	—	—	16.6
Coposil	—	158.6	156.0	—	18.6	15.9
Basicop	189.0	144.0	—	16.1	—	21.6
Bordow	204.0	162.5	—	14.0	—	—
Bordeaux	212.3	171.3	160.3	16.2	14.5	15.9

INJURY TO FRUIT AND FOLIAGE

Apples:—Observations were made in both the 1939 and 1940 tests of the spray materials to determine their relative toxicity to the foliage of the apples and cherries and to the fruit of the apples. Conditions were very favorable for copper injury during the seasons of 1939 and 1940.

Bordeaux gave the greatest injury in 1939 to both Golden Delicious and Jonathan apple finally resulting in considerable defoliation of the trees. Other materials showing toxicity of commercial concern were Cuprocide 54y and Basicop. Cupro K, Coposil, and Copper Compound A gave some injury which, however, was not severe. Sprays which resulted in little or no injury to the foliage were Bordow and Z.O.

In 1940 the apple varieties used, Rome Beauty and Ben Davis, were injured considerably by the copper sprays. Yellow Cuprocide caused slightly more injury than Bordeaux but the toxicity exhibited by both of these materials was severe. Although Copper Compound A showed no injury to the Rome Beauty it caused rather severe burning on the Ben Davis. The injury from Coposil was not as great as from Bordeaux Mixture or Yellow Cuprocide yet was enough to be of commercial concern.

All the spray materials used in 1939 caused russetting of the fruit of the apples sufficient to be of commercial importance, with the exception of Z.O. and lime sulfur. The conditions under which the 1940 experiments were made, being very favorable for copper injury, also resulted in extreme russetting of the apple fruit with most of the materials applied. Copper Compound A was the only material which did not cause severe injury to the fruit.

Cherries:—On the cherry plots Yellow Cuprocide, similar to its action on the apple, resulted in extensive defoliation while Basicop, Coposil, Copper Hydro 40, Cupro K, and Copper Compound A showed evidence of only a slight amount of spray burn. Lime sulfur, Bordeaux, and Bordow caused no obvious burning of cherry foliage in these experiments.

Control of Disease

An indication of the fungicidal value of the spray materials tested was obtained during the 1940 season at the University Fruit Farm cherry orchard. Cherry leaf spot began appearing on some of the check trees about June 20th. By July 10th certain of the check trees showed a moderate amount of defoliation. The trees sprayed with Lime sulfur and Basicop had approximately 15 per cent of their leaves infected with leaf spot by July 10th. The trees sprayed with Copper Compound A, Copper Hydro 40, and Coposil had a slight amount of leaf spot appearing with approximately 5 per cent of the foliage yellowing due to the fungous organism. Trees sprayed with Cupro K, Yellow Cuprocide, Spray Cop, and Bordeaux Mixture showed no appearance of leaf spot.

Adherence to Foliage

While the amount of copper found on a leaf surface may not always be representative of the fungicidal value present, it is obvious that a very low percentage of copper retained after spraying would indicate a lack of protective value against fungous attack. Bordeaux Mixture is known to have excellent adhesive qualities (2). An examination of Table II will show that Cuprocide 54y showed more resistance to weathering on both varieties of apples, Jonathan and Golden Delicious, and on the Montmorency cherry than did Bordeaux; although Bordeaux was second to Cuprocide 54y among the materials tested. Very good conditions for weathering were obtained when 6.27 inches of rain fell during a two week period after the materials had been applied. On the apples Copper Compound A and Z.O. showed the least resistance to weathering, the test for copper being negative following the two week rainy period. No copper from Cupro K was found on the Golden Delicious foliage and only a slight amount was found on the Jonathan foliage after the weathering period. While the resistance to

TABLE II—Tenacity of Insoluble Copper Sprays to Apple and Cherry Foliage

Spray Material	Cherries			Apples					
	Montmorency			Golden Delicious			Jonathan		
	Initial Deposit	Residue After 2 Weeks	Adherence (Per Cent)	Initial Deposit	Residue After 2 Weeks	Adherence (Per Cent)	Initial Deposit	Residue After 2 Weeks	Adherence (Per Cent)
Cuprocide 54y..	4.7*	4.2*	89.3	7.8*	4.2*	53.7	8.6*	5.6*	69.2
Hydro 40......	7.0	4.5	64.2	8.4	1.5	17.8	19.9	7.2	35.8
Bordeaux......	16.7	9.2	55.0	15.2	7.3	48.1	19.3	9.3	48.1
Copper Phosphate........	15.1	6.2	41.0	16.7	2.1	17.4	30.4	6.9	22.8
Bordow........	7.4	3.0	40.5	8.3	2.3	23.0	13.6	1.3	9.6
Cupro K.......	5.1	1.9	37.2	4.1	0.0	0.0	6.8	0.5	6.6
Z. O..........	2.2	0.8	36.3	6.7	0.0	0.0	8.8	0.0	0.0
Copper Compound A.....	8.9	1.3	14.6	9.9	0.0	0.0	19.8	0.0	0.0
Basicop........	12.9	1.3	10.0	12.5	1.1	8.4	—	—	—

*Milligrams of copper per 500 square centimeters of leaf area (One leaf surface considered).

weathering of these spray materials expressed as percentage adherence of metallic copper did not maintain the same order in all the tests made, it is possible to group them as resistant or non-resistant to weathering action. Those which may be classed as resistant on the basis of these tests are Cuprocide 54y, Bordeaux Mixture, Copper Hydro 40, and Copper Phosphate. The materials which showed lack of resistance to weathering are Z.O., Copper Compound A, and Basicop. Cupro K and Bordow tend toward an intermediate position. A marked difference was also found in the initial amount of copper deposited on the foliage by the various spray materials.

Summary and Conclusions

In this investigation Bordeaux Mixture was found to be undesirable to use on sour cherries due to a dwarfing action on the fruit and foliage. It was also undesirable for use in early season apple sprays due to burning of the foliage and russetting of the fruit. Several of the proprietary copper sprays were found to cause rather severe injury under the conditions of the tests.

In tests made for the control of the fungous organism causing cherry leaf spot Bordeaux Mixture, Cupro K, Yellow Cuprocide, and Spray Cop were found to be adequate.

Bordeaux Mixture and Copper Phosphate were found to have both the largest initial deposit of copper on the leaves and the best adhesive qualities.

Two materials which combined control of the fungous with freedom from injury to the plant were Cupro K and Spray Cop and, according to this investigation, may offer promise as substitutes for Bordeaux Mixture.

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The Bordeaux Formula in Horticultural Research[1]

By E. P. Christopher, *Rhode Island Agricultural Experiment Station, Kingston, R. I.*

A QUOTATION from a recent paper by McCallan and Wilcoxon states (7), "that fifty years of experimentation with copper compounds have given us none equal to Bordeaux mixture". In spite of its failings, Bordeaux is being used more or less generally for the control of diseases. It is quite generally considered the standard fungicide (12). It has come to the writer's attention on a number of occasions that there is some lack of uniformity in the understanding of any given formula for Bordeaux. Much research has been or is being carried on involving very accurate and expensive equipment for measuring not only toxicity but photosynthesis, respiration, and transpiration and it would seem reasonable to suspect some of the apparent differences in results to be due to differences in interpretation of formula. We have been interested at the Rhode Island station for several years in the standardization of fungicides (4) but have found, even among our own group, considerable difference of opinion. The excellent paper by Wilcoxon and McCallan (12) is a step in the right direction and it suggested to the writer that a survey of workers in the horticultural field to determine their understanding of the meaning of a 4–4–50 Bordeaux would be of value.

A single page survey blank was sent to workers in all parts of the United States and to several in Canada. Purposely, several blanks were often sent to the same college or university. The response was quite gratifying and 77 blanks were finally used in tabulation. There were 40 institutions represented. In a good many instances one person was delegated to answer for the institution, showing a desire for uniformity which has real merit. As might be expected, some blanks were not filled out completely but in most cases at least 73 answers were available for each question.

Results of the Survey

The first question involved the meaning of the first and second figure "4" in the common formula 4–4–50. Of 77 answering the question, 67, or 87 per cent, said the first figure meant 4 pounds of copper sulphate, and a minority of 10, or 13 per cent, thought of it as 4 pounds of some form of lime. In the second part of the question, 10 specified copper sulphate and the remaining 67, some form of lime. Twenty-six mentioned calcium oxide; 32, hydrated lime; one, both; and 18, lime without any specification as to form. Many in the last group indicated their preference as to form, later in the survey.

A series of questions was asked regarding the method of mixing the spray. Of 70 answering the question as to which was added first, copper sulphate or lime of some form, 44 put in the copper sulphate first, 21 put in the lime first, and five put them in together. Fifty-eight favored diluting the copper sulphate before combining, while 18 favored

[1]Contribution No. 571 of the Rhode Island Agricultural Experiment Station.

using it in a more concentrated form. Only 38, however, felt it necessary to dilute the lime.

Another question had to do with the form of copper sulphate used. While a number of different terms were used including 27 powder, 16 snow, 29 crystals, technical, spray grade, C. P., and so on, there is probably no real difference in the resulting spray. Convenience or the local supply probably determined the choice. Practically everyone used hydrated lime, 70 out of 77. Only three regularly used stone lime but the most important figure may be the 20 denoting the small number who, while using hydrated lime, adjusted to an equivalent of 4 pounds of calcium oxide. This means that early data reported on Bordeaux on the basis of 4 pounds of calcium oxide or equivalent and recent data by others (2, 11) is in reality on the basis of different amounts of active agents when compared with data published by most workers. Moreover, as has been pointed out by Butler (1), the difference in the mixing method may also result in a different spray.

The question of high calcium or high magnesium lime was answered, 63 for high calcium, seven for high magnesium, and three for either one. Of these 73, 45 had a real preference while 28 took what was offered for sale locally. Only 10 bother to test for free copper using potassium ferrocyanide, probably assuming a surplus of lime. Twenty-nine reported experiments just completed or in progress involving Bordeaux. Of those carrying on experiments, only five indicated that an adjustment to a calcium oxide equivalent basis was made.

In several cases suggestions of value were made under remarks. Among other things it was suggested that the formula should be expressed in terms of 100 gallons instead of 50. Different formulae may be of value in special cases. We concur in the first case and recognize the truth of the second. We used 4–4–50 simply as a sample formula to secure interpretation.

Discussion

This survey, involving 40 institutions well distributed, would seem to point out a glaring source of error in experimental results having to do with Bordeaux. That one in eight does not agree with the majority as to which figure means copper sulphate and which means some form of lime is especially surprising. In discussing the Bordeaux formula informally with several workers from different sections of the country, there seems to be a very provincial feeling about the formula's interpretation.

It is apparent that most workers are using the hydrated lime because it is so easily obtained and requires no slaking before use. However, the general disregard of the meaning of the original formula makes for considerable confusion in the interpretation of results. Some investigators (5, 11) have assumed spray injuries from Bordeaux to be due to free copper. Shutak and Christopher (8), Horsfall (3), and others have noted serious injury due to lime. Southwick and Childers (9) have data to indicate interference with carbon dioxide assimilation by high lime.

Bordeaux mixture at best is a very complex material. After very

careful studies, Wilcoxon and McCallan (11) describe it as "an adsorption complex, or a solid solution containing copper, lime, and sulphate, the copper of which is soluble in water to an extent which varies with its composition". They report low lime as giving a greater initial copper content in solution, a more rapid increase in soluble copper, and a more rapid loss of total copper. It has been pointed out by McCallan and Wilcoxon (6) that fungicidal action is related to the amount of copper soluble and not to total available. The quantity of lime used in the formula apparently has its influence on the amount soluble and the time at which the greatest amount accumulates.

Wilson and Runnels (10) noted a difference in the effect of calcium and magnesium limes. They report magnesium lime as less able to prevent copper injury to coleus plants than similar amounts of calcium lime. They also report different transpirational effects from methods of mixing and copper lime ratios.

It would seem from these survey data and the experimental evidence available that a uniform interpretation of Bordeaux formula would be very desirable. Only in that way can results be considered comparable. The excellent start by members of the Phytopathological Society toward a uniform method for toxicity tests and a comparison of copper sprays on the basis of copper per acre deserves commendation. It would seem, however, that the matter should be carried further to include collaboration with the horticulturists and physiologists on matters of lime and mixing. Certainly all results involving the use of Bordeaux should include a definite statement as to formula interpretation and mixing methods. It might also be advisable to standardize on a formula for 100 gallons since most other sprays are spoken of in that way.

Conclusion

It is apparent that much of the conflicting data on the influence of Bordeaux sprays may be attributed to the use of different materials and combinations. Standardized formula and methods would seem desirable. An effort should be made by the various societies involved to bring about standardization and careful explanation of materials used in experimental work.

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The Toxicity of Certain Spray Chemicals to the Roots of Apple, Grape, Rye, and Corn

By N. F. Childers, *Ohio Experiment Station, Wooster, Ohio*

Abstract

This paper will be published in full in the *Ohio Experiment Station Bimonthly Bulletin.*

DELICIOUS apple seedlings were grown in potted soil which contained either lead arsenate, lead chloride, or sodium arsenate. The arensic in lead arsenate appeared to be more toxic to the roots of apple than the lead. Thus, 20 parts per million of arsenic in the form of sodium arsenate had a slight stimulating effect on growth of tops and roots, but 60, 80, 100 and 160 parts per million caused progressively less growth. Most of the plants died in soil containing 100 and 160 parts per million of arsenic. However, soil containing lead as lead chloride at the same concentrations caused little or no reduction in growth even at 160 parts per million when compared with the checks. Arsenic in the form of lead arsenate was less toxic to the roots at a given concentration than arsenic in the form of sodium arsenate.

Further tests have been made with rye, apple and grape which were grown in gravel and supplied with full nutrient solutions pumped to them automatically twice a day. Arsenic as sodium arsenate, lead as lead chloride, and copper as copper sulphate were added to the nutrient solutions in various concentrations. Arsenic appeared to be more toxic to the grape than to rye and apple. There was a slight stimulating effect of 20 parts per million of arsenic to apple and rye but a marked depressing effect occurred in case of the grape. Fifty and 200 parts per million of lead in the nutrient solution caused no effect or a slight increase in growth of both apple and grape. The grape tolerated more copper in the solution than the apple. There was a progressive decrease in growth of both apple and grape, however, when copper was increased at intervals of 5 from 10 to 30 parts per million. Very poor growth was obtained at 30 parts per million of copper.

In the higher concentrations of arsenic grape leaves, especially at the tip of the shoots, turned yellow except for the veins which remained green. The internodes were shorter and terminal buds formed earlier. About the same held true for the apple except that the lower leaves on a shoot turned yellow first and dropped. Apple leaves on such plants were usually thinner and somewhat flacid.

Corn often grows poorly for a few years on land which has been cleared of an old orchard. Tests carried out in the greenhouse with potted corn plants show that there are reductions in growth of stalks and size of ears when arsenic as sodium arsenate was increased from 5 to 100 parts per million. At concentrations of 80 and 100 parts per million of arsenic the kernels rarely developed. The leaves on corn plants which were growing in high concentrations of arsenic in the soil showed yellowish areas which ran parallel with the greener veins. The internodes on such plants were shorter and the tassels and silks appeared later.

Common Spray Materials Alter the Internal Structure of Apple Leaves[1]

By Wm. F. Pickett and C. J. Birkeland, *Kansas Agricultural Experiment Station, Manhattan, Kans.*

IN 1932, a project was organized at the Kansas Agricultural Experiment Station for the purpose of studying the internal structure of apple leaves. In 1933, Pickett (1) stated that certain varieties of apple leaves differed in their internal structure when measurements were made from permanently mounted cross sections. His studies in 1934 (2) indicated that apparent photosynthetic activity and internal structure of apple leaves are correlated. Leaves with the more extensive internal space were more active in carbon assimilation than leaves with a more compact internal structure. This was observed when different leaves of the same variety were compared as well as when two or more varieties were used.

The chlorophyll content of York and Wealthy leaves was determined in 1937 (3) for the purpose of observing the influence of the chlorophyll content on the rate of photosynthetic activity. The leaves of these two varieties contained practically the same amount of chlorophyll a plus b per unit area but the Wealthy leaves possessed greater internally exposed surface than those of the York, and the Wealthy trees also made a significantly greater gain in dry matter per unit of leaf area than York. From the 1938 (4) studies, it was deduced that the extent of the internally exposed surface of apple leaves is more important than the chlorophyll content as a factor partially governing photosynthetic activity.

Materials and Methods

The purpose of the studies reported in this paper was to discover if certain spray residues affect the ratio of the internally exposed surface to the externally exposed surface of apple leaves. The experiments were run in two series — one in a greenhouse and one in the field.

Greenhouse Series:—On January 29, 1940, 22 2-year-old trees of each of the Wealthy and York varieties were planted in 12-inch clay pots and plunged into a ground bed in a greenhouse. Soon after the first new leaves began to appear, one-half of the trees of each variety were sprayed at weekly intervals with a spray composed of 2½ gallons of 33 degrees Beaume liquid lime-sulfur and 4 pounds of arsenate of lead in 100 gallons. These applications caused no apparent injury to the foliage. The other trees were not sprayed.

Shortly after the ninth spray application, five leaves were collected from each tree. The leaves selected were average in size for the tree and grew near the middle portion of the new shoots. Portions of the leaves near the midribs and midway between the basal and apical ends were selected for the microscopical study. Only one piece, about 1 by 3 centimeters, was taken from a single leaf.

[1]Contribution No. 171, Department of Horticulture.

Mounted sections were prepared for microscopic study. Five sets of slides were made for each tree, each set consisting of one slide of cross sections and one of tangential sections. Each set of slides was made from the same leaf. Two pages of camera lucida drawings at a magnification of 1760x were made from each set of slides. Each page of drawings included the following: One drawing of a field 50 microns square of each of the first, second, and third layers of palisade cells from a tangential slide; one drawing of a field of spongy mesophyll 50 microns square from a tangential slide; and one drawing of a field 50 microns wide across the spongy mesophyll, in cross section.

Measurements of the drawings were made with a chartometer and a planimeter. By using the formula developed by Turrell (5) the ratio, R, of the internally exposed surface to the externally exposed surface was calculated for each leaf collected.

Field Series:—On March 28, 1940, 10 2-year-old trees of the York and Jonathan varieties and six 2-year-old Wealthy trees were planted outdoors.

Beginning on May 4, 1940, one-half of the trees of each variety were sprayed weekly and the other half were left as unsprayed checks. The first six applications consisted of 2½ gallons of 33 degrees Beaume lime-sulfur and 4 pounds of arsenate of lead per 100 gallons of spray, the next three applications were of lead arsenate alone at the above strength, and the last five applications consisted of lead arsenate plus 2 per cent summer oil emulsion.

On August 5, representative leaves were collected, killed, fixed, and imbedded, using the same method as with the greenhouse grown leaves. Likewise, the same procedure was followed for making the drawings and calculations of the R values.

Presentation of Data

Greenhouse Grown Leaves:—As shown in Table I, the Wealthy leaves had greater values than the York leaves in these characteristics: (a), R value; (b), depth of palisade tissue; and (c), diameter of cells in the first layer of the palisade tissue. The York leaves had the greater number of cells in the first layer of the palisade tissue per unit of leaf area.

Within each variety the sprayed leaves had: (a), A smaller R value; (b), less depth of palisade tissue; (c), smaller average diameter of the cells in the first layer of the palisade; and (d), a greater average number of cells in the upper layer of the palisade per unit of leaf area.

TABLE I—Average Measurements of Greenhouse Grown Leaves (1940)

Variety	Treatment	R Value	Depth of Palisade Tissue (Microns)	Diameter of Cells in First Layer of Palisade Tissue (Microns)	Number of Cells in First Layer of Palisade Tissue Per 2500 Square Microns of Leaf Area
Wealthy.....	Not sprayed	13.40	104.49	9.95	32.48
Wealthy.....	Sprayed	10.71	90.86	8.82	34.80
York........	Not sprayed	9.44	68.84	9.46	35.85
York........	Sprayed	6.88	52.92	8.36	39.35

An analysis of variance shows that the variance between the varieties was highly significantly greater than the variance within either variety for (a), R value; (b), depth of palisade tissue; (c), diameter of cells in the first layer of the palisade; and (d), number of these cells per unit of leaf area. This indicates that the mean differences in these characteristics were due to varietal differences rather than to tree variation within the varieties. The variance between the sprayed and unsprayed leaves was highly significantly greater than the variance between leaves of individual trees indicating that the mean differences were due to the sprays rather than to tree variation. The unsprayed leaves had a significantly greater R value than the sprayed leaves.

The variance between depths of the palisade tissues indicates that the differences between varieties and also between the sprayed and unsprayed foliage were highly significant. The unsprayed foliage contained deeper or thicker palisade tissue than the sprayed leaves, and likewise, the unsprayed leaves possessed a highly significantly smaller number of cells in the first layer of the palisade tissue per unit of leaf area than the sprayed specimens. The cross diameter measurements of the first layer of the palisade cells in the unsprayed leaves were highly significantly greater than in the sprayed samples.

Field Leaves:—The measurements for the field grown leaves are presented in Table II.

The data in Table II show the Wealthy leaves possessed the greatest R value. The York leaves were lowest in this value, and the Jonathan leaves were intermediate. The same ranking applies to the depths of the palisade tissue. Within each variety, the unsprayed foliage showed a higher R value, the palisade tissue was deeper, the diameters of the first layer of palisade cells were smaller, and there were a greater number of palisade cells in the first layer per unit of leaf area than in the sprayed leaves. These values are averages based on measurements of 260 pages of camera lucida drawings from the 6 Wealthy, 10 Jonathan, and 10 York trees used in this experiment, or 10 sets of drawings for the foliage of each tree.

An analysis of variance for the R values reveals that the variance between varieties was significantly greater than the variance between trees. The variance between the sprayed and unsprayed leaves was significantly greater than the variance between trees, indicating that the mean differences found were due to the spraying rather than to tree variation. The same statements apply to the depth of the palisade tissues.

TABLE II—Average Measurements of Field Grown Leaves (1940)

Variety	Treatment	R Value	Depth of Palisade Tissue (Microns)	Diameter of Cells in First Layer of Palisade Tissue (Microns)	Number of Cells in First Layer of Palisade Tissue Per 2500 Square Microns of Leaf Area
Wealthy.....	Not sprayed	15.30	117.08	10.24	31.57
Wealthy.....	Sprayed	11.96	103.64	8.20	35.93
Jonathan.....	Not sprayed	13.54	99.60	9.34	35.72
Jonathan.....	Sprayed	10.26	83.29	7.81	37.52
York........	Not sprayed	11.63	83.35	9.64	36.78
York........	Sprayed	7.71	60.93	8.25	37.06

An analysis of variance of the average diameters of the first layer of palisade cells shows no significant difference between the varieties. However, the variance between the treatments was highly significantly greater than the variance between the trees, and apparently the differ-

FIG. 1. Cross sections of Wealthy apple leaves. A, Unsprayed; B, Sprayed. The palisade tissue in the unsprayed leaves is thicker than in the sprayed ones.

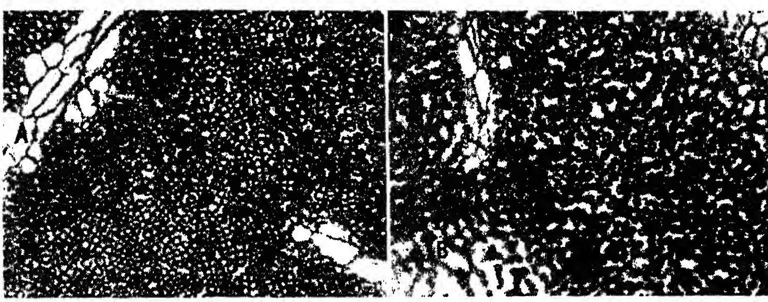

FIG. 2. Tangential sections of York apple leaves. First layer palisade cells of (A) unsprayed, (B) sprayed leaves. There are more cells in the first layer of the palisade per unit of leaf area in the unsprayed specimens.

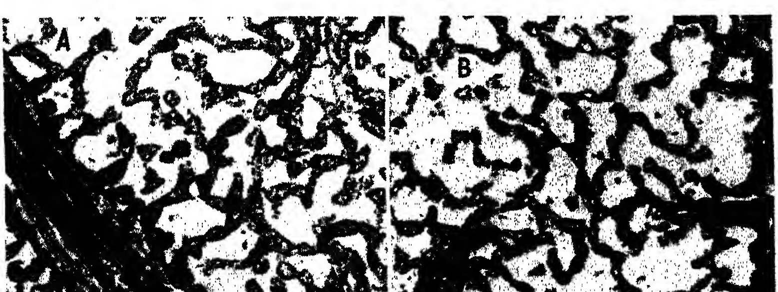

FIG. 3. Tangential sections of Wealthy apple leaves. Spongy mesophyll in (A) unsprayed, (B) sprayed specimens. Normal cell appearance in unsprayed leaf may be observed.

ences were due to the spraying instead of variation between the trees. When the average number of first layer palisade cells per unit of area is considered, the variance between the varieties was highly significantly greater than the variance between the trees. The sprayed leaves had a highly significantly larger number of upper layer palisade cells per unit area than the unsprayed leaves.

The correlation and regression coefficients calculated from covariance in which the R values and depths of the palisade tissue for all varieties, for both the sprayed and unsprayed leaves, and for both the greenhouse grown and field grown leaves were used are +.954 and 7.58 respectively. This is of interest because the calculation of the R value may be greatly simplified. Instead of making a great number of difficult measurements and calculations as is necessary with Turrell's (5) formula, the R value may now be computed directly from direct microscopic measurements of the depth of the palisade tissue.

Illustrations of some representative leaves are presented in Figs. 1 to 3 inclusive.

Interpretation of Results

According to the cited studies at the Kansas Station, the extent of the internally exposed surface of leaves of certain apple varieties is important among the factors which condition the rate of photosynthesis. The data presented in this paper show that the ratio of the internally exposed surface to the external surface of both greenhouse grown and field grown apple leaves is reduced by the repeated applications of certain spray materials.

In an unpublished Master's thesis, A. L. Kenworthy at the Kansas Station in 1939 reported that approximately 85 per cent of the internally exposed surface of apple leaves is found in the palisade tissue. This is in agreement with the present study. The presence of certain spray residues on the foliage results in a greatly altered palisade tissue, and it seems logical that this may account for the greatly reduced amount of internally exposed surface in the sprayed leaves.

It seems to be justifiable, therefore, to conclude that part of the reduction in photosynthetic activity resulting from repeated applications of certain spray materials may be due to the changes brought about in the internal structure of the leaves.

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The Influence of Excess Water in the Soil on Transpiration and Apparent Photosynthesis of Young Apple Trees

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Abstract

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TRANSPIRATION and apparent photosynthesis of young Stayman-Winesap trees were determined before and after excess water was added to the soil in which the test trees were growing. Check trees were watered regularly but not in excess. All trees were grown in the greenhouse before they were placed under test. The Heinicke-Hoffman apparatus for measuring transpiration and carbon dioxide assimilation was employed. Two series of determinations were performed on a total of six trees in the environment-control chamber and two series of experiments were performed outside the greenhouse on a total of five trees. In the chamber the temperature was constant at 85 degrees F in one experiment and 80 degrees F in another, relative humidity at 50 per cent, and light averaged from 2000 to 5000 foot candles at the surface of the test and check leaves.

Apparent photosynthesis and transpiration usually showed somewhat similar reductions after the soil was flooded. In the chamber experiments a reduction of 10 to 40 per cent occurred in both processes within 6 to 9 days. Two trees showed significant reductions the first day after flooding. Reductions of 25 to 95 per cent resulted after flooding for a total of 15 and 30 days. When excess water was drained at the time of greatest reduction in leaf activity, there usually was a trend to recovery within 4 to 6 days. Subsequently, both processes remained completely recovered, or, as in some cases, showed a trend downward again even though the soil was not in a flooded condition.

With trees flooded outside of the greenhouse the reductions in leaf activities varied considerably depending mainly upon the evaporating power of the air and the intensity of sunlight. One tree in July showed a marked reduction in photosynthesis and transpiration by the second day after flooding and by 8 days showed a 75 per cent reduction. Marginal and tip burning occurred on the leaves and the experiment was discontinued. Photosynthesis and transpiration of another tree showed reductions of 35 per cent in 9 days. The soil was drained and recovery occurred within 5 days. Ninety per cent or larger reductions occurred within 15, 18 and 26 days, respectively, for three other test trees flooded from late September to late October.

Symptoms of leaf injury in all experiments first appeared on the lower leaves and progressed acropetally. Abscission of two to four leaves often occurred before termination of the experiments. Leaves on trees flooded in late June in the chamber developed light green areas between the veins. The foliage wilted and drooped from the outer ends of the petioles. The petioles did not droop, however. Leaves on trees

flooded in November in the chamber showed only a greater development of anthocyanin pigment by the termination of the experiment.

Leaves on trees flooded outdoors in July showed similar injury to those flooded in late June in the chamber. Leaves on trees flooded from late September to late October outdoors were slower in developing injury. Lower leaves showed yellowish red splotches which finally became necrotic. They also curled upward at the margins but did not droop. Upper leaves appeared similar to the checks except for the presence of considerable anthocyanin pigment.

A Leitz "Ultrapak" microscope was used to observe daily stomatal behavior over a 3-day period in an experiment in the chamber. No apparent differences in opening of stomata were found between flooded and check trees, although photosynthesis and transpiration during this period showed reductions of about 85 per cent.

The roots of plants used in two series of experiments were washed free of soil at the end of the determinations. The only outstanding external difference between the flooded and check roots was the appearance of several short, rather stubby, white roots on or near the main root stocks of the treated trees.

The Effect of Leafhopper Injury on the Rates of Apparent Photosynthesis and Transpiration of Stayman Winesap Apple Leaves

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Abstract

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A SERIES of experiments are in progress at Ohio State and Purdue Universities in which measurements are being made on the effect of leafhopper injury on the rates of apparent photosynthesis and transpiration of apple leaves. An experimental orchard at Orleans, Indiana, where a variety of leafhopper studies are under way, is used as a convenient source of leafhoppers. The insects are shipped by Special Delivery to Ohio, where they are caged over apple shoots outdoors, in the greenhouse, or in the environment-control chamber in the Horticulture Building. The rates of photosynthesis and transpiration are measured by the Heinicke and Hoffman method before and after insect feeding. The insects are permitted to feed on one group of leaves while another group is maintained as an uninjured check.

In a typical experiment 100 leafhoppers per leaf were caged over a Stayman Winesap whip and permitted to feed for 3 days. This treatment, which consisted of 7,200 "leafhopper-hours" per leaf, resulted in a reduction of 23.2 per cent in the rate of photosynthesis and 15.8 per cent in the rate of transpiration. It can be inferred from these data that 300 leafhoppers per leaf (assuming an area of 50 square centimeters for each of the leaves) would cause a reduction of 1 per cent in the rate of photosynthesis and ⅔ per cent in the rate of transpiration in the first hour. An additional 9600 leafhopper-hours caused a further reduction of 7.6 per cent in photosynthesis and 12.7 per cent in transpiration. Further data in this and other experiments bear out the apparent "break" in the curve when these results are plotted, and it was not until very severe injury was affected that further marked reductions occurred. Continued feeding eventually gave the entire leaf surface a greenish-yellow appearance and reduced photosynthesis 72.0 per cent and transpiration 50.9 per cent.

When 1940 field populations of leafhoppers were reproduced on experimental leaves in the chamber, the data indicate that at a point corresponding to May 17 in the field in Southern Indiana the rate of photosynthesis was reduced 16.5 per cent and transpiration 4.9 per cent. At a point corresponding to June 25, photosynthesis and transpiration were reduced 19.2 and 13.8 per cent respectively, and by July 26, they were reduced 27.1 and 12.9 per cent respectively. It is important that this injury, most of which occurs early in the season, is permanent on a given leaf, and that the injured area cannot be expected to recover later in the season, even though the insects are eventually brought under control.

Compilation of Data on Nut Weight and Kernel Percentage of Black Walnut Selections

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A SUSTAINED interest in the eastern black walnut, *Juglans nigra* L., as a crop tree has been maintained over a period of at least 30 years by the Northern Nut Growers Association and other workers, and consequently, a considerable number of selections of this species has been reported. However, descriptions of the nut characteristics of particular selections are not readily available in convenient form. It is the purpose of this paper to present a compilation of data found in the literature and to report additional data collected during the last 4 years.

In seeking for selections of high quality whose adaptability to the Tennessee Valley region might be tested with the ultimate purpose of establishing suitable varieties, it became necessary to review the data on available selections and to secure nut samples for further study.[1] The review of previously published data should be useful to workers seeking better selections for their respective regions. The new data resulting from the study of nut samples secured for further observation adds materially to information on variation in selections from year to year. It is hoped that this compilation may stimulate the reporting of hitherto unpublished black walnut data.

The compilation of data is presented in tabular form and includes 335 entries on 212 selections. *Selection* represents the name or designation of the black walnut selection as it appears in the literature, except that in the case of previously unpublished data, a selection name has been assigned. *Nut Weight* is reported as the average weight in grams per nut. *Kernel Percentage* is

$$\frac{\text{Weight of kernel} \times 100}{\text{Weight of whole nut}}.$$

Since no entirely satisfactory method of describing cracking quality of the nut in numerical terms has yet been devised, and since some workers did not report this feature of the nut on a uniform basis, data on cracking quality are omitted. *Source of Nuts* is given as the state in which the tree furnishing the nut sample was located. In most cases this source represents the original tree, since samples from several sources are reported only for Asbury, Creitz, Edras, Grundy, Mintle, Myers, Ohio, Stabler, Stambaugh, Ten Eyck, Thomas, Todd, and Vandersloot. Where more than one source is given, the first source listed represents the original tree, except for the horticultural varieties Ohio, Stabler, and Thomas, where all the samples are from grafts. *Crop Year* is self-explanatory. *Worker* is the person or agency which reported the data. Most of these data result from nut contests sponsored by the Northern Nut Growers Association and from tests and follow-up work of its members.

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[1]Acknowledgment is made to all persons who cooperated by supplying nut samples.

Selection	Nut Weight (Grams)	Kernel Percentage	Source of Nuts	Crop Year	Worker
Adams	14.5	26.2	Mich.	1929	Bixby (4)†
Adams	11.6*	24.56	Mich.	1930	Reed (11)
Adams	10.6	25.1	Mich.	1936	T.V.A.
Adams, Lucille	18.9	20.6	Mich.	1929	Bixby (4)
Aldred	18.6	16.7	Ont.	1929	Bixby (4)
Allen	13.3*	23.86	Mich.	1931	Reed (11)
Allen	15.0	27.0	Mich.	1939	T.V.A.
Allen, J. E.	11.1	17.1	Ont.	1929	Bixby (4)
Alley	9.9	24.8	N. Y.	1918	Bixby (1)
Alley	11.1*	25.57	N. Y.	1931	Reed (11)
Alley	10.7	27.7	N. Y.	1937	T.V.A.
Alley, A.A.	15.8	20.9	N. Y.	1919	Bixby (2)
Armknecht No. 1	28.9	23.9	Iowa	1918	Bixby (1)
Armknecht No. 2	28.0	20.3	Iowa	1918	Bixby (1)
Arnold Arboretum	6.1	14.8	N. Y.	1919	Bixby (2)
Asbury	29.6	28.0	Ky.	1926	Bixby (3, 4)
Asbury	23.7	15.2	N. Y.	1937	MacDaniels (10)
Atkins	16.3	28.2	Ind.	1926	Bixby (3)
Attoway	20.0	27.5	Va.	1934	T.V.A.
Axline	19.8	27.4	Ohio	1939	T.V.A.
Aygarn	28.4	20.9	Va.	1939	T.V.A.
Baird	23.1	20.4	N. Y.	1937	MacDaniels (10)
Baker	31.8	19.5	Ind.	1929	Bixby (4)
Beck	12.3*	33.08	N. Y.	1930	Reed (11)
Belleville	20.8	27.4	Pa.	1938	T.V.A.
Benge	28.4	22.1	Texas	1937	T.V.A.
Benton	15.3	27.58	N. Y.	1934	Drake (6)
Benton	14.38	26.1	N. Y.	1934	MacDaniels (9)
Benton	18.2	24.6	N. Y.	1937	MacDaniels (10)
Bethel	23.9	25.2	Ohio	1939	T.V.A.
Betty Lou	17.16	27.03	Mo.	1932	Drake (6)
Biggs	13.7	27.0	Ind.	1926	Bixby (3, 4)
Biggs	21.5	23.8	Ind.	1938	T.V.A.
Blackburn	14.8	29.7	Md.	1918	Bixby (1)
Bliss	10.9	31.9	Md.	1939	T.V.A.
Bloss	13.7*	24.4	Ind.	1934	Reed (11)
Bloss	13.4	27.3	Ind.	1937	T.V.A.
Bomberger	16.4	23.8	Pa.	1919	Bixby (2)
Bontz	16.2	28.0	Ill.	1926	Bixby (3)
Booth	18.13	31.21	Va.	1931	Drake (12)
Booth	15.6*	31.64	Va.	1931	U.S.D.A. (12)
Bowman	34.9*	23.53	Va.	1931	U.S.D.A. (12)
Broughman	15.53	27.62	Va.	1931	Drake (12)

*Nut weight adjusted from data reported as number of nuts per pound.
**Average of samples from same tree.
†Numbers in parenthesis refer to literature cited.

Selection	*Nut Weight (Grams)*	*Kernel Percentage*	*Source of Nuts*	*Crop Year*	*Worker*
Broughman	15.1*	29.87	Va.	1931	U.S.D.A. (12)
Burke	19.73	26.35	Mo.	1930	Drake (5)
Burns	16.4	26.6	Iowa	1936	Lounsberry (7)
Burton	26.2	23.7	Ky.	1926	Bixby (3, 4)
Burton	30.7	25.8	Ky.	1938	T.V.A.
Burton No. 1	23.4	17.1	Ky.	1929	Bixby (4)
Burton No. 2	18.6	21.0	Ky.	1929	Bixby (4)
Bybee	23.06	24.4	Ky.	1939	T.V.A.
Caldwell	22.62	23.42	Va.	1931	Drake (12)
Calhoun No. 1	15.8	28.9	Mich.	1939	T.V.A.
Campbell	22.8	21.5	Ark.	1929	Bixby (4)
Cargill	16.9	20.1	N. Y.	1934	MacDaniels (9)
Cargill	12.8	23.3	N. Y.	1937	MacDaniels (10)
Clark	17.42	29.27	Minn.	1934?	Drake (6)
Climax	14.6	29.5	Mich.	1938	T.V.A.
Cochrane	16.6	32.4	Wis.	1938	T.V.A.
Coe	15.1	25.8	N. Y.	1934	MacDaniels (9)
Coe	11.8	18.0	N. Y.	1937	MacDaniels (10)
Cold Stream No. 14	11.0	20.0	B. C.	1929	Bixby (4)
Cooper	27.97	30.49	Ark.	?	Drake (6)
Creitz	14.5	27.6	Ind.	1926	Bixby (3)
Creitz	17.11	30.04	Ind.	1930	Drake (5)
Creitz	17.69	28.45	Ind.	1932	Drake (6)
Creitz	19.4	20.1	N. Y.	1937	MacDaniels (10)
Creitz	19.2	23.5	N. Y.	1937	MacDaniels (10)
Creitz	17.4	29.2	Ark.	1938	T.V.A.
Cresco	13.0*	29.18	Iowa	1930	Reed (11)
Dougherty	16.9	26.63	Mo.	1930	Drake (5)
Dougherty	19.5	23.2	Mo.	1939	T.V.A.
Doyle	15.6	24.4	Mich.	1929	Bixby (4)
Drake	17.7	24.3	Ohio	1926	Bixby (3)
Durham	17.8	29.2	Iowa	1929	Bixby (4)
Durham	16.4	32.56	?	1930	Drake (5)
Edgewood	15.49	28.95	Ark.	1930	Drake (5)
Edras	18.1	33.7	Iowa	1926	Bixby (3, 4)
Edras	15.16	32.78	Iowa	1930	Drake (5)
Edras	15.07	32.31	Ark.	1931	Drake (6)
Edras	14.8	24.8	N. Y.	1937	MacDaniels (10)**
Edras	16.6	29.1	Ark.	1938	T.V.A.
Ellis	13.14	31.81	Mo.	1930	Drake (5, 6)
Emerson	18.0	20.1	N. Y.	1937	MacDaniels (10)**
Fellows	15.6	28.1	N. Y.	1934	MacDaniels (9)
Finnegan	11.1	30.2	Ind.	1939	T.V.A.
Freel	19.3	31.6	Iowa	1929	Bixby (4)
Fritz	11.5	28.7	Ohio	1926	Bixby (3)

*Nut weight adjusted from data reported as number of nuts per pound.
**Average of samples from same tree.
†Numbers in parenthesis refer to literature cited.

Selection	Nut Weight (Grams)	Kernel Percentage	Source of Nuts	Crop Year	Worker
Fyre	38.0	22.9	N. C.	1929	Bixby (4)
Galena	17.37	25.5	Mo.	1930	Drake (5)
Garrett	26.1	22.5	Ky.	1938	T.V.A.
Garrett	22.0	20.9	Ky.	1939	T.V.A.
Gieske	34.6	19.5	Tenn.	1939	T.V.A.
Gilman	13.2	32.5	Iowa	1936	Lounsberry (7)
Gilman	19.3	27.3	Iowa	1938	T.V.A.
Graybill	16.06	26.96	Va.	1931	Drake (12)
Graybill	16.2*	25.0	Va.	1931	U.S.D.A. (12)
Green Forest	13.01	25.59	Mo.	1930	Drake (5)
Greentree	20.1	18.7	Ala.	1939	T.V.A.
Gregory	20.7	23.7	Va.	1929	Bixby (4)
Grundy	21.1	25.6	Iowa	1929	Bixby (4)
Grundy	13.0*	31.66	Iowa	1931	Reed (11)
Grundy	15.59	28.8	Iowa?	1930	Drake (5, 6)
Grundy	16.0	14.6	N. Y.	1937	MacDaniels (10)
Grundy	22.8	28.2	Ark.	1938	T.V.A.
Haag	16.8	22.6	Ind.	1929	Bixby (4)
Hare	20.4	27.0	Ill.	1926	Bixby (3, 4)
Hare	23.1	29.7	Ill.	1938	T.V.A.
Harney	19.7	32.6	Ky.	1939	T.V.A.
Harris	17.29	26.6	Mich.	1930	Drake (5)
Hartford	26.0	26.9	Ky.	1938	T.V.A.
Henegar	23.1	21.8	Ala.	1938	T.V.A.
Henegar	21.8	22.0	Ala.	1939	T.V.A.
Hepler	14.29	31.28	Mich.	?	Drake (6)
Hicks	13.6	22.8	N. Y.	1919	Bixby (2)
Hilton	18.1*	21.12	N. Y.	1933	Reed (11)
Hilton	16.2	18.6	N. Y.	1937	MacDaniels (10)
Hobbs	25.3	27.2	Va.	1926	Bixby (3, 4)
Homann	26.2	22.9	Iowa	1918	Bixby (1)
Homeland	24.4	27.04	Va.	1931	Drake (12)
Homeland	25.2*	12.30	Va.	1931	U.S.D.A. (12)
Hopwood	22.4	24.1	Ill.	1926	Bixby (3, 4)
Hopwood	15.4	28.6	Ill.	1938	T.V.A.
Horton (Meyers)	23.91	30.44	Iowa	?	Drake (6)
Hostetter	17.3	26.0	Pa.	1929	Bixby (4)
Huber	15.96	34.33	Wis.	1930	Drake (5, 6)
Huber	14.1	32.8	Wis.	1938	T.V.A.
Hunter	24.3	26.7	Mo.	1929	Bixby (4)
Impit	19.2	25.5	B. C.	1929	Bixby (4)
Impit	18.01	22.32	B. C.	1929	Drake (5)
Impit	19.3	24.8	B. C.	1936	T.V.A.
Jim Lang	21.5	28.8	Iowa	1936	Lounsberry (7)
Jordon	22.46	26.89	Mo.	1929?	Drake (5)

*Nut weight adjusted from data reported as number of nuts per pound.
**Average of samples from same tree.
†Numbers in parenthesis refer to literature cited.

Selection	Nut Weight (Grams)	Kernel Percentage	Source of Nuts	Crop Year	Worker
Kautz	31.8	22.7	Ohio	1939	T.V.A.
Kelling	19.4	32.4	Iowa	1926	Bixby (3, 4)
Kelling	22.09	25.84	?	?	Drake (5)
Kenney	26.6	23.3	Ky.	1939	T.V.A.
Ketchum No. 9	20.1	23.4	Ohio	1919	Bixby (2)
Ketchum No. 10	14.1	25.5	Ohio	1919	Bixby (2)
Kettler	13.9	32.5	Wis.	1937	T.V.A.
Kiefer	25.4	23.6	Ky.	1918	Bixby (1)
Kingery	24.61	28.03	Va.	1931	Drake (6, 12)
Kirkpatrick	21.6	21.8	Tenn.	1926	Bixby (3)
Kirkpatrick	24.4	20.3	Tenn.	1938	T.V.A.
Kirkpatrick	17.3	19.0	Tenn.	1939	T.V.A.
Knapke	18.9	29.1	Ohio	1926	Bixby (3, 4)
Korn	15.0	30.8	Pa.	1937	T.V.A.
Korn	17.2	28.9	Pa.	1938	T.V.A.
Korn	16.7	29.8	Pa.	1939	T.V.A.
Lamm	20.7	25.1	Ill.	1929	Bixby (4)
Lang	20.5	22.4	Ohio	1919	Bixby (2)
Lawrence	19.18	24.5	Mo.	1929?	Drake (5)
Learn	16.9	23.1	Ont.	1929	Bixby (4)
Learn	17.9	24.7	Ont.	1937	T.V.A.
Lee	19.0	27.1	Va.	1931	Drake (12)
Lee	20.6*	26.47	Va.	1931	U.S.D.A. (12)
Lenoir	25.4	22.1	Tenn.	1938	T.V.A.
Lindauer	12.6	23.8	Ill.	1926	Bixby (3)
Lisbon	20.2	28.6	Ohio	1939	T.V.A.
Lonestar	25.1	23.5	Texas	1939	T.V.A.
Lucas	16.1	29.2	Ind.	1926	Bixby (3)
Lutz	26.4	24.6	N. C.	1918	Bixby (1)
MacDonald	18.0	29.4	Iowa	1936	Lounsberry (7)
Marion	22.8	26.5	Iowa	1929	Bixby (4)
Marion	16.6	28.31	?	?	Drake (5)
Mark	15.8	25.3	Ohio	1926	Bixby (3, 4)
Mark	15.2	24.9	Ohio	1937	T.V.A.
Mark	15.1	24.5	Ohio	1939	T.V.A.
Mark, C. E.	14.1	19.9	Ohio	1929	Bixby (4)
Martin	20.9	25.7	Iowa	1939	T.V.A.
McClaren	29.2	22.9	Tenn.	1939	T.V.A.
McMillen	21.46	28.23	Mich.	?	Drake (6)
McPherson	18.25	25.7	N. Y.	1934	MacDaniels (9)
Metcalf	19.0	25.2	Iowa	1929	Bixby (4)
Metcalf	21.07	22.72	?	?	Drake (5)
Meyers Bros.	24.4	26.6	Md.	1926	Bixby (3)
Mintle	17.2	30.8	Iowa	1929	Bixby (4)
Mintle	12.63	31.9	Iowa	1931	Drake (5)

*Nut weight adjusted from data reported as number of nuts per pound.
**Average of samples from same tree.
†Numbers in parenthesis refer to literature cited.

Selection	Nut Weight (Grams)	Kernel Per-cent-age	Source of Nuts	Crop Year	Worker
Mintle	14.2	30.56	Iowa	?	Drake (6)
Mintle	8.65	23.6	N. Y.	1937	MacDaniels (10)**
Mintle	14.7	31.1	Ark.	1938	T.V.A.
Monterey	24.54	27.75	Pa.	1930	Drake (6)
Monterey	23.2	28.9	Pa.	1938	T.V.A.
Morton, L. E.	20.1	21.4	Va.	1926	Bixby (3)
Morton, W. M.	20.3	22.2	N. C.	1926	Bixby (3)
Moses	22.6	19.4	Ohio	1929	Bixby (4)
Myers	7.8	32.0	Ohio	1926	Bixby (3, 4)
Myers	11.6	33.2	Pa.	1939	T.V.A.
Niederhauser	22.7	29.5	Iowa	1936	Lounsberry (7)
Nocka	17.8	29.8	Ohio	1939	T.V.A.
Oakes	17.04	31.6	Ill.	?	Drake (6)
Ogden	20.7	26.6	Ky.	1926	Bixby (3, 4)
Ohio	17.3	32.4	?	1929	Bixby (4)
Ohio	16.07	29.24	?	1930	Drake (5)
Ohio	17.64	28.79	Ark.	1932	Drake (6)
Ohio	15.85	24.7	N. Y.	1932	MacDaniels (8)
Ohio	17.15	29.1	Va.	1932	MacDaniels (8)
Ohio	14.9	32.9	Iowa	1936	Lounsberry (7)
Ohio	14.8	16.6	N. Y.	1937	MacDaniels (10)
Ohio	17.0	31.3	Pa.	1938	T.V.A.
Ohio	15.5	30.0	Pa.	1938	T.V.A.
Ohio	18.7	30.9	Ark.	1938	T.V.A.
Ohio	16.7	29.4	Pa.	1939	T.V.A.
Ohio	18.1	29.3	Md.	1939	T.V.A.
Orr	31.5	23.6	Ala.	1938	T.V.A.
Osterloh	19.5	25.59	Mo.	1929	Drake (5)
Patterson	15.1	31.1	Iowa	1926	Bixby (3, 4)
Patterson	17.3	29.48	Iowa	1930	Drake (5)
Pearl	22.7	26.4	Iowa	1926	Bixby (3)
Pella	19.5	30.4	Iowa	1938	T.V.A.
Penticon No. 1	18.8	22.3	B. C.	1929	Bixby (4)
Penticon No. 2	16.2	24.1	B. C.	1929	Bixby (4)
Pinecrest	22.95	27.14	Pa.	1931	Drake (6, 12)
Pinecrest	22.7*	27.19	Pa.	1931	U.S.D.A. (12)
Plummer	14.0	24.3	Mich.	1929	Bixby (4)
Post	24.2	20.0	N. Y.	1934	MacDaniels (9)
Powell	15.6	27.2	Tenn.	1939	T.V.A.
Powers	26.5	24.6	W. Va.	1926	Bixby (3)
Pursell	20.1	29.4	Iowa	1937	Lounsberry (7)
Redmond	19.55	20.0	N. Y.	1934	MacDaniels (9)
Redmond	21.0	21.9	N. Y.	1937	MacDaniels (10)
Rice	17.7	26.6	Ky.	1938	T.V.A.
Richterkessing	18.0	24.4	Mo.	1929	Bixby (4)
Riehl	19.0	22.6	Ill.	1926	Bixby (3)

*Nut weight adjusted from data reported as number of nuts per pound.
**Average of samples from same tree.
†Numbers in parenthesis refer to literature cited.

Selection	Nut Weight (Grams)	Kernel Percentage	Source of Nuts	Crop Year	Worker
Ripley No. 1	14.3	25.6	Ohio	1918	Bixby (1)
Ripley No. 2	15.2	26.4	Ohio	1918	Bixby (1)
Ripley, J. E.	26.7	23.6	Ohio	1919	Bixby (2)
Robinette	27.9	23.7	Va.	1926	Bixby (3, 4)
Rohwer	20.4	28.4	Iowa	1926	Bixby (3, 4)
Rohwer	18.61	27.09	Iowa	1930	Drake (5, 6)
Rohwer	15.6	27.9	Iowa	1932	MacDaniels (8)
Rohwer	17.9	25.9	Iowa	1938	T.V.A.
Ruddick	17.12	28.56	Ark.	?	Drake (5, 6)
Ruddick	18.1	25.9	Ark.	1937	T.V.A.
Salvisa	22.4	26.8	Ky.	1939	T.V.A.
Sanders	15.6	20.0	Pa.	1929	Bixby (4)
Schimmoller	14.4	29.9	Ohio	1926	Bixby (3, 4)
Schock	18.5	27.0	Ind.	1926	Bixby (3)
Scott	32.9	22.7	Ky.	1939	T.V.A.
Shireman	14.7	25.2	Pa.	1926	Bixby (3)
Sifford	20.6	32.0	Va.	1937	Lounsberry (7)
Sim	13.6	20.6	Ont.	1929	Bixby (4)
Smith	24.7	27.2	Ohio	1939	T.V.A.
Snyder	18.3	27.2	N. Y.	1934	MacDaniels (9)
Snyder	16.3	26.3	N. Y.	1938	MacDaniels (10)**
Snyder	16.4	28.0	N. Y.	1938	T.V.A.
Snyder	21.3	24.7	N. Y.	1939	T.V.A.
Speer	39.1	22.6	Texas	1938	T.V.A.
Stabler	16.8	33.8	Md.	1926	Bixby (4)
Stabler	14.7	17.0	?	1926	Bixby (4)
Stabler	17.66	30.18	?	?	Drake (5)
Stabler	14.73	31.22	Ark.	1930?	Drake (6)
Stabler	13.8	15.1	N. Y.	1937	MacDaniels (10)
Stabler	13.9	16.8	N. Y.	1937	MacDaniels (10)
Stambaugh	21.8	29.8	Ill.	1926	Bixby (3, 4)
Stambaugh	16.35	28.62	Ill.	1931?	Drake (6)
Stambaugh	15.45	23.95	N. Y.	1937	MacDaniels (10)**
Stanley	14.97	26.25	Va.	1931	Drake (12)
Stanley	14.6*	27.4	Va.	1931	U.S.D.A.(12)
Stevens	19.7	29.54	Va.	1931	Drake (12)
Stevens	19.7*	30.52	Va.	1931	U.S.D.A. (12)
Stillman	25.4	19.3	N. C.	1929	Bixby (4)
Stillman	26.25	21.6	N. C.	?	Drake (5)
Stockman	36.7	18.0	La.	1929	Bixby (4)
Stoney Brooke	21.8	18.3	N. Y.	1937	MacDaniels (10)
Stout	12.4	32.2	Ohio	1926	Bixby (3, 4)
Susan	23.2	29.43	Mo.	?	Drake (6)
Tasterite	12.87	28.05	N. Y.	?	Drake (5, 6)
Tasterite	12.6*	28.14	N. Y.	1930	Reed (11)
Tasterite	13.85	27.1	N. Y.	1932	MacDaniels (8)

*Nut weight adjusted from data reported as number of nuts per pound.
**Average of samples from same tree.
†Numbers in parenthesis refer to literature cited.

Selection	Nut Weight (Grams)	Kernel Per-cent-age	Source of Nuts	Crop Year	Worker
Teall	13.5	19.3	Ont.	1929	Bixby (4)
Ten Eyck	16.7	21.0	N. J.	1919	Bixby (2)
Ten Eyck	18.94	27.77	Ill.	1930	Drake (5)
Ten Eyck	20.09	32.55	Ark.	1932	Drake (6)
Ten Eyck	16.6	32.5	Iowa	1936	Lounsberry (7)
Ten Eyck	14.1	21.65	N. Y.	1937	MacDaniels (10)**
Ten Eyck	17.0	30.3	Pa.	1938	T.V.A.
Thomas	19.7	23.9	Iowa	1919	Bixby (2, 4)
Thomas	21.15	29.78	Ark.	1930	Drake (5, 6)
Thomas	24.45	22.9	N. Y.	1932	MacDaniels (8)
Thomas	20.9	29.2	Iowa	1936	Lounsberry (7)
Thomas	18.3	21.0	N. Y.	1937	MacDaniels (10)
Thomas	24.0	22.1	N. Y.	1937	MacDaniels (10)
Thomas	16.7	25.2	N. Y.	1937	MacDaniels (10)
Thomas	18.5	26.0	N. Y.	1937	MacDaniels (10)
Thomas	16.8	19.8	N. Y.	1937	MacDaniels (10)
Thomas	18.8	19.0	N. Y.	1937	MacDaniels (10)
Thomas	20.3	26.0	Pa.	1937	T.V.A.
Thomas	21.8	25.7	Okla.	1937	T.V.A.
Thomas	18.0	30.0	Md.	1938	T.V.A.
Thomas	18.1	28.1	Pa.	1938	T.V.A.
Thomas	23.1	27.3	Ky.	1938	T.V.A.
Thomas	23.7	24.4	Ark.	1938	T.V.A.
Thomas	21.5	22.8	Va.	1938	T.V.A.
Thomas	23.9	27.0	Tenn.	1938	T.V.A.
Thomas	25.0	29.0	Pa.	1939	T.V.A.
Thomas	20.9	26.3	Pa.	1939	T.V.A.
Thomas, Ind.	22.7	22.9	Ind.	1929	Bixby (4)
Throp	13.1	18.3	Ind.	1926	Bixby (3, 4)
Thrush	22.6	21.7	Ill.	1929	Bixby (4)
Tilley	32.2	25.8	N. C.	1926	Bixby (3, 4)
Todd	26.75	26.0	Ohio	1932	MacDaniels (8)
Todd	22.4	25.0	N. Y.	1937	MacDaniels (10)
Todd, W.	14.0	22.1	Ont.	1929	Bixby (4)
Towers	15.72	26.6	N. Y.	1934	MacDaniels (9)
Toy	21.9	20.5	W. Va.	1919	Bixby (2)
Trebine	23.0	28.6	Ohio	1939	T.V.A.
Troup	19.3	23.4	Ont.	1937	T.V.A.
Tucker	18.0	28.0	Tenn.	1934	T.V.A.
Unaka	22.3	21.9	Va.	1937	T.V.A.
Unaka	23.5	19.1	Va.	1939	T.V.A.
Vandersloot	34.0	21.4	Pa.	1926	Bixby (3, 4)
Vandersloot	23.3	14.8	N. Y.	1937	MacDaniels (10)
Vandersloot	30.7	22.2	Pa.	1938	T.V.A.
Walker	16.7	19.2	Colo.	1929	Bixby (4)
Wallace	24.8	28.0	Tenn.	1939	T.V.A.

*Nut weight adjusted from data reported as number of nuts per pound.
**Average of samples from same tree.
†Numbers in parenthesis refer to literature cited.

Selection	Nut Weight (Grams)	Kernel Per-cent-age	Source of Nuts	Crop Year	Worker
Wanda	15.34	31.49	Iowa	?	Drake (6)
Warehine	14.4	28.4	Ohio	1926	Bixby (3)
Weatherby	14.3	25.2	Va.	1926	Bixby (3)
Weltner	17.0	29.4	Pa.	1929	Bixby (4)
Werner	30.4	21.4	Iowa	1919	Bixby (2)
Wetzel	16.4	27.4	Pa.	1929	Bixby (4)
Wetzel	14.19	27.76	Pa.	1930	Drake (5)
Wetzel	16.2	28.3	Pa.	1937	T.V.A.
Witty	26.2	24.0	Ill.	1926	Bixby (3)
Worley	24.0	25.0	N. C.	1934	T.V.A.
Worley	24.0	20.5	N. C.	1937	T.V.A.
Worthington	20.57	21.87	Iowa	1930?	Drake (5)
Wright	16.2	23.8	N. Y.	1934	MacDaniels (9)
Wright	15.8	14.6	N. Y.	1937	MacDaniels (10)
Wright, D. C.	22.25	23.1	N. Y.	1932	MacDaniels (8)
Yawger	20.3	22.2	N. Y.	1919	Bixby (2)
Young	22.9	23.4	Ohio	1939	T.V.A.
Zeke	20.7	27.7	Ky.	1939	T.V.A.
Zeta	23.8	27.6	Ky.	1939	T.V.A.

*Nut weight adjusted from data reported as number of nuts per pound.
**Average of samples from same tree.
†Numbers in parenthesis refer to literature cited.

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A Royal Apricot Sport of Short Chilling Requirement: Origin and Transmission of Characteristics to Seedlings

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THE winters of coastal Southern California are usually too mild for normal leafing and fruiting of the apricot (1). Little progress has been made in the development of high quality mild winter apricots mainly because varieties or seedlings with short chilling requirements were not available. Recently, however, a group of such seedlings has been obtained in a rather unusual way and a brief description of their origin is accordingly of interest.

In 1936, J. C. Watt of the Armstrong Nurseries showed the author two young trees propagated from a sport of the Royal apricot. The buds were obtained in 1934 from A. D. Shamel of the United States Department of Agriculture at Riverside, who in turn got them from B. A. Van Duine of Cabazon, California. In a letter written October 16, 1940, Shamel states that the sport branch was first noticed by Van Duine in March 1934 because of its early flowering and normal development while the balance of the tree and other trees in the orchard were seriously affected by delayed foliation following the warm winter of 1933–34. The parent tree was then 19 or 20 years old and had two main limbs, one of which divided into three branches. The sport branch arose on the southwest side of the center limb about 5 feet above ground. It had apparently started its growth in 1932 or 1933 and was about 4 feet long and bearing 10 fruits when first observed by Shamel and associate Pomeroy, May 7, 1934.

In the spring of 1937 following the unusually cold winter, the young Royal and so-called Early Royal trees leafed and flowered simultaneously, thus indicating that earliness of the sport in previous years was in reality due to a difference in reaction to warm winter effects. Unfortunately the sport seemed to have a poor bearing habit in that few short fruit-spurs were formed and most of the fruit was born on the ends of long year-old shoots. In the 1940 season, the Early Royal trees, then about 6 years old, had a better crop due to the greater number of short fruiting spurs. Evidently the poor bearing habit is gradually being outgrown, but the fruit lacks color and so the sport would seem to have little commercial promise.

In 1937 flowers of the two young trees were pollinated with Newcastle pollen and others were self-pollinated in order to see if the early leafing habit would be transmitted. Reciprocal crosses of the Royal and Newcastle were also made for comparison. Fruit from these crosses and self-pollinations was harvested and embryos cultured in the summer of 1937. The young trees resulting were transplanted to the field in the spring of 1938 and records as to leafing were made in 1939 and 1940, both years of rather severe delayed foliation. A few open-pollinated seeds of the Royal were cultured in 1938 and records of the resulting seedlings were taken in the spring of 1940. The leafing behavior of the parents, seedlings and hybrids is shown in Table I. Some F. P. I. introductions from North Africa, kindly supplied by

TABLE I—COMPARATIVE LEAFING OUT OF F. P. I. INTRODUCTIONS, ROYAL, EARLY ROYAL, NEWCASTLE, SELFED, AND HYBRID SEEDLINGS IN 1939 AND 1940

Variety	Season	Leafing Out Beginning Feb				Leafing Out Beginning Mar				Leafing Out Beginning Apr		Totals
		3–7	8–15	16–23	23–29	1–7	8–15	16–23	24–31	1–7	8–15	
F.P.I. 91614	1939	—	—	—	—	—	—	—	2	—	—	2
88809	1939	—	—	—	—	—	—	—	2	—	—	2
88887	1939	—	—	—	—	—	—	2	—	—	—	2
88605	1939	—	—	—	—	—	—	2	—	—	—	2
88601	1939	—	—	—	—	—	—	2	—	—	—	2
Royal	1939	—	—	—	—	—	—	—	2	—	—	2
	1940	—	—	—	—	—	—	—	2	—	—	2
Early Royal	1939	—	—	—	—	2	—	—	—	—	—	2
	1940	—	—	—	—	2	—	—	—	—	—	2
Newcastle	1939	—	—	—	—	—	—	2	—	—	—	2
	1940	—	—	—	—	—	—	2	—	—	—	2
Royal selfed	1940	—	—	—	—	—	—	3	4	1	2	10
Early	1939	10*	—	—	—	1	—	—	1	9	—	21
Royal selfed	1940	2	1	—	7	1	—	3	2	5	—	21
Newcastle ♀ ×	1939	—	—	—	—	—	1	13	12	—	—	26
Royal ♂	1940	—	—	—	—	1	3	22	—	—	—	26
Early Royal ♀ ×	1939	6*	—	—	—	—	—	—	—	2	—	8
Newcastle ♂	1940	—	1	2	2	—	1	1	—	1	—	8
Royal ♀ × Newcastle ♂	1940	—	—	7†	1	1	28	25	4	1	2	69

*Terminal buds only began leafing out February 3 to 7, 1939; other buds were later and trees had new leaves generally well developed by March 15, 1939.

†Terminal buds only began leafing out February 19, 1940; other buds were later and trees did not generally begin leafing out until March 15, 1940.

C. O. Hesse of the United States Department of Agriculture at Davis, California for comparative trial are also included.

Evidently the F. P. I. introductions are not much better adapted to mild winters than Newcastle and so would be of little value in breeding work. All the seedlings which leafed-out in any given week are grouped together in order to present the data more compactly.

As may be noted, seven trees in the progeny of Royal ♀ × Newcastle ♂ were earlier leafing than Newcastle. These were definitely weak trees, however, and so would probably be of little value in further breeding work. In the smaller population of Newcastle ♀ × Royal ♂ the earliest seedling did not begin leafing out until March 6, 1940. In striking contrast is the behavior of the progeny of Early Royal ♀ × Newcastle ♂. Not only are many trees here very early in beginning to leaf-out as noted in the table, but they also were in full foliage much earlier than even the most advanced of the Royal ♀ × Newcastle ♂ hybrids (Fig. 1). Furthermore they were vigorous trees and flowered and bore fruit in the 1940 season when only 3 years old.

Thus far only 10 open-pollinated Royal seedlings have been grown. All were seriously affected by the mild 1939–40 winter. While earlier leafing types might segretate out if a larger population were grown, it seems doubtful if any would be found as early as those obtained in the selfed Early Royal progeny. Here 10 out of 21 trees began leafing at terminal buds the first week of February 1939, and were in full leaf before most of the Royal ♀ × Newcastle ♂ seedlings had even started. The contrast was even more striking in 1940, following the mildest winter of record. Then the earliest seedling began leafing February 5, and rapidly came into full leaf. Others following as indicated in the

FIG. 1. Showing relatively dormant condition of Newcastle ♀ × Royal ♂ hybrid at left compared with Early Royal ♀ × Newcastle ♂ hybrid 37108/7 at right on March 19, 1940.

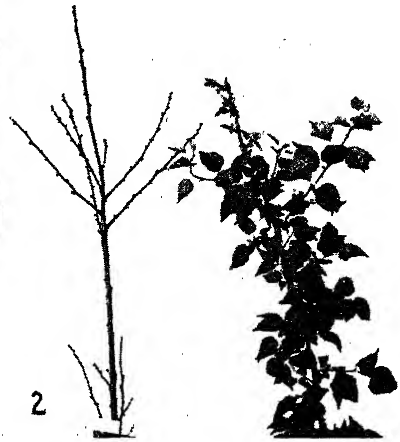

FIG. 2. Showing dormant condition of Royal selfed seedling at left compared with Early Royal selfed seedling 37109/2 at right on March 19, 1940.

table until 10 were well leafed-out by February 29 (Fig. 2). There was some scattering as indicated in leafing of the other 11 trees until finally a group of five trees began leafing on April 5, and even then were very slow in completion of leafing out, bare areas being still present on April 15.

The combined evidence would then seem to show that the Early Royal sport not only transmits its lower chilling requirement, but behaves much like hybrid peach varieties such as Babcock, which are very little affected by delayed foliation, *i.e.*, the factors for this characteristic are dominant and the sport is heterozygous. Analysis of the factorial basis must await development of true breeding lines, so that the effect of possible modifying factors may be studied by growing of adequate F_2 and backcross progenies. Possibly only one major dominant factor is involved.

The hybrid trees which fruited varied in that some bore their fruit on short spurs instead of at the end of long shoots, thus indicating the possibility of separating the poor fruiting habit of the sport from its low chilling requirement.

So far as can be determined from the literature this is one of the few cases in which a sport of a horticultural variety of fruit has been shown to transmit its characteristics. Should it prove possible to separate its highly desirable low chilling requirement from its poor fruiting habit and fruit quality, as preliminary studies indicate, this sport may prove valuable as a basis for developing apricots adapted to mild winter regions.

Grateful acknowledgment is made to A. D. Shamel of the United States Department of Agriculture for calling attention to the Royal

sport and to Armstrong Nurseries where the writer was employed while carrying on this investigation. The cooperation of J. C. Watt of the Armstrong Nurseries is particularly appreciated.

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Photosynthesis, Transpiration, and Growth of Apple Trees as Influenced by Various Concentrations of Oxygen and Carbon Dioxide in the Soil Atmosphere

By W. H. Childs, *West Virginia University, Morgantown, W. Va.*

Abstract

This material will be published in full in *Plant Physiology*.

ONE- and two-year-old budded McIntosh and Delicious apple trees were grown in a sandy loam soil in 2-quart glass jars and 2-gallon glazed pots. Various concentrations of oxygen and carbon dioxide were maintained in the soil atmosphere either by varying the rate at which a stream of air was drawn through or by limiting gaseous diffusion, and the effect on photosynthesis, transpiration, and growth was measured.

Such quantitative criteria of growth as fresh weight, dry weight, ash, leaf area, and terminal growth indicated that there was no appreciable depressing effect as the oxygen concentration was decreased until there was slightly less than 12 per cent present, when a distinct drop was noted. A further gradual depression of growth was apparent as the oxygen concentration was decreased below this point, but there was no other abrupt drop until a concentration of 1½ to 2 per cent was reached. Lowering the oxygen concentration below this point, however, resulted in a second distinct drop. The slight growth which occurred with less than 1½ per cent of oxygen about the roots was apparently at the expense of previously stored materials, since the fibrous roots were found to be dead when harvested.

The concentration of carbon dioxide present, within the limits found in this study, had little effect on growth or on photosynthesis and transpiration. There may have been a slight depressing effect of high carbon dioxide concentrations, but this was so slight as to be negligible when compared to the effect of low oxygen concentrations.

Neither photosynthesis nor transpiration of individual healthy leaves was decreased until the oxygen concentration about the roots was 2 per cent or less. This was true both for trees which were grown under the various concentrations of oxygen and for those which were grown with a normal soil atmosphere and then had this adjusted while determinations were made.

Qualitative examination of the root systems showed that they could be placed in four groups on the basis of various characteristics. Those trees grown with more than 12 per cent of oxygen about the roots had a large, reddish-brown, fibrous root system with the new growth chiefly on the end of long, fibrous roots, and with no lenticular proliferations. Where the oxygen concentration had been between 2½ and 11 per cent, the root system was smaller, medium brown in color, and showed a few lenticular proliferations on the upper part of the tap root. The new growths were partially on the end of long fibrous roots and partially on the tap root and large side roots slightly below

the soil surface. Those trees grown with from 1½ to 2½ per cent of oxygen present had a distinctly different type of root system. The lower roots showed very little lignification, and some of them may have been dead. There were a large number of long, unlignified roots arising on the tap root and on the large side roots close to the soil surface, together with many lenticular proliferations which may have been the point of origin of these roots. These roots were quite brittle and were easily broken off in harvesting. With less than 1½ per cent oxygen present, the fibrous roots were dead, the large roots were very dark in color, and there were no new growths of any kind.

It is apparent, if these data are applicable to apple trees grown in the orchard, that there will be a depression of growth if the percentage of oxygen in the soil atmosphere remains less than 12 per cent for any considerable period of time, as has been found to be the case in certain heavy soils at depths of 2 feet or more. This emphasizes the importance of the selection of an orchard soil which will provide good aeration for the trees' roots, if maximum growth and yields are to be realized.

Cultural Practices for Young Apple Trees[1]

By E. P. Christopher, *Rhode Island Agricultural Experiment Station, Kingston, R. I.*

FRUIT growers are continually seeking the best and most economical method of starting young trees. Several methods involving more or less care during the first few years are being used. Data on growth responses from six cultural methods without fertilizer are presented below.

Materials and Methods

In the spring of 1939, 30 McIntosh and 30 Baldwin 1-year whips were divided into six groups of as near equal size and vigor as possible and planted on a gravelly knoll of Narragansett stony loam. Six plots of one McIntosh and one Baldwin tree each were distributed over the area and replicated four times. No fertilizer was applied and no pruning done. All trees were planted as uniformly as possible using the soil at hand with the exception of those in treatment No. 1. In this case a 12-quart pailful of moistened horticultural peat was mixed with the soil placed about the roots.

The trees were subjected to the following treatments: 1, Planted with 12 quarts of peat moss and then kept continually under clean cultivation; 2, maintained under clean cultivation; 3, mulched with 3 to 4 inches of rye straw and non-legume hay; 4, planted to unfertilized pasture sod; 5, planted to quack grass, and 6, given clean culture from May through August and then sown to winter rye.

Results

The 1939 growing season was extremely dry in Rhode Island, a deficiency of 5.43 inches accumulating during May, June, and July. The first real rain to break this dry spell fell on August 17. In spite of this lack of moisture, good growth was made (4). In Table I are presented the average terminal growth for 1939 and 1940 and trunk diameters for 1940.

It is interesting to note that under the conditions existing, a well aerated gravelly soil and an extremely dry season in 1939, there was no significant difference between the trees receiving peat and those planted without the benefit of the peat. It has been pointed out (8) that under certain dry conditions an increased root growth without an appreciable difference in top growth may occur. Since further results are desired from the trees, none were dug to note root development.

The trees in the plots with pasture sod and quack grass were very definitely inferior to all others. This was very noticeable in the color and size of the leaves. This suggests an unsuccessful competition for nitrogen and water. Lyon, Heinicke and Wilson (6) seemed to find the effect of sod on nitrates of more importance. Baker (2) reports a close correlation between trunk circumference and terminal growth and total nitrogen in the soil. While the difference in growth between the two sod treatments is not significant for the average of both years, quack

[1]Contribution No. 584 of the Rhode Island Agricultural Experiment Station.

grass was somewhat superior for 1940 alone and there was a noticeably better green coloring of the leaves. As has been pointed out by Langord (5) the demands of various grasses, both as to amount and time, may have an influence. This type of information for orchard covers seems to be limited.

TABLE I—TERMINAL GROWTH AND TRUNK DIAMETER OF McINTOSH AND BALDWIN APPLE TREES UNDER SIX CULTURAL TREATMENTS

Treatment	McIntosh		Baldwin	
	Terminal Growth Average 1939–1940 (Inches)	Trunk Diameter 1940 (Inches)	Terminal Growth Average 1939–1940 (Inches)	Trunk Diameter 1940 (Inches)
Peat moss and clean cultivation	205	0.98	250	1.09
Clean cultivation	211	1.10	281	1.14
Mulch—straw	296	1.27	373	1.29
Pasture sod	109	0.83	136	0.84
Quack grass	89	0.86	155	0.82
Clean cultivation and cover crop	250	1.10	322	1.10
Difference needed for significance.. Method of variance	86	.20	93	.21

Clean culture with cover crops gave next to the highest terminal growth but the mulch treatment would appear to be significantly better than any other. Leaves were large and deep green in color and growth continued late in the season. It will be recalled that no fertilizer had been applied. Boynton and Batjer (3) report that 2 years of mulch resulted in no significant increase in organic matter. Proebsting (7) reported that 10 years of cover crops did not increase either nitrogen or moisture holding capacity. Wiggan (9) also reported good results with non-legume mulch and no fertilizer but does not suggest why. Anthony (1) feels that more attention should be given to the surface layer of soil, especially emphasizing the factors of moisture penetration and accumulation. Unfortunately no soil moisture or nitrogen determinations were made in our study. Further work along this line is planned.

CONCLUSIONS

From these preliminary data it seems that under certain conditions peat moss does not improve the growth of young apple trees. Planting trees in sod land, at least without fertilizers, is definitely inferior to other treatments. Mulch provides excellent apple tree growth without fertilizer and at a very low labor cost.

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Peach Breeding: A Study of Inheritance in Some Cross-Bred Seedlings[1]

By H. L. LANTZ and T. J. MANEY, *Iowa Agricultural Experiment Station, Ames, Ia.*

THIS is a preliminary report of experimental breeding of the peach with respect to hardiness of tree and fruit bud in inter-specific crosses and in two strains of selected peaches. Standard varieties of peaches are not hardy in the Upper Mississippi Valley. Winter temperatures have repeatedly killed the trees or the fruit buds and spring frosts often kill the blossoms. There are a few varieties and some orchards of seedling trees that have survived the winters and which have a reasonably good record for production.

There are three general approaches to the problem of securing improved varieties by breeding: (a) inter-varietal crosses; (b) inter-specific crosses; and (c) the growing of seedlings from selected parents.

In 1905 the late Professor S. A. Beach brought pits of the Hill's Chili peach to Ames, Iowa from New York. At that time, Hill's Chili was regarded as one of the hardiest varieties grown. By 1916 a third generation of seedlings had been grown at Ames. One tree which bore white-fleshed fruits was later named Polly. Somewhere in the history of these seedlings, natural crossing brought white-fleshed peaches of the Champion type into the progenies. The best seedlings of the third generation of Hill's Chili, both white and yellow fleshed, were propagated and planted in 12-inch clay pots in 1924, and since that time some of the breeding work has been done in the greenhouse. Trees of several desired varieties and of *Prunus davidiana* were also potted.

Trees of *Prunus davidiana* are known to have stood 35 to 40 degrees below zero. The tree is of roundish, upright habit; it grows rapidly; the bark is dark reddish with distinct grey lenticels. The dark green foliage resembles that of the peach in shape, but the leaves are somewhat shorter and narrower and have a much smoother surface. The fruit buds seldom survive the winter temperatures. If there is a survival, the buds burst into bloom 2 to 3 weeks earlier than the normal peach blooming season. The fruit of *P. davidiana* is about ¾ to 1 inch in diameter; the pit is plump, roundish, free and covered with a little more than ⅛ inch of coarse, fibrous flesh. The color of the fruit is pale green; and its pale green flesh is practically inedible. Since the tree possesses desirable vigor, hardiness and disease-resistant foliage, it has been used in inter-specific crosses with the peach.

A number of years ago Harlow Rockhill, amateur fruit breeder of Conrad, Iowa, successfully crossed the Bailey and *Prunus davidiana*. The trees of the first generation cross have stood through a number of winters and have attained considerable size. These trees are much hardier than the peach. Their fruits are larger than those of *P. davidiana* and some are fairly edible. Potted trees of *P. davidiana*

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bloom profusely under greenhouse conditions. The blossoms open within 3 to 5 days after being warmed up and produce an abundance of viable pollen. In 1928 crosses of *P. davidiana* were made in the greenhouse and seedling trees of these crosses were tubbed and grown in the greenhouse for use in further breeding. These F_1's have proved to be sterile or nearly so when selfed but when crossed with peaches have set fruit in sufficient numbers to provide considerable F_2 material.

A number of F_1's and F_2's were planted in the orchard in 1937, 1938, 1939 and 1940. The trees of the 1937 planting bore abundantly in 1939 and several bore fair crops in 1940. Their blooming season varies from a week earlier to nearly as late as that of the peach. None of these seedlings bloom as early as *Prunus davidiana*. The fruits of all these seedlings are larger than those of *P. davidiana,* have more flesh around the pit and several were fairly edible. Two seedlings bore fruits 2 inches in diameter. Fruits of nearly all seedlings are green to pale green in color and have either white or pale greenish flesh. Two seedlings were fruited in 1940 which bore yellow-fleshed fruits. The fruits are all freestone.

The trees have distinct characteristics of the *Prunus davidiana* in both the F_1 and F_2 generations. The bark color and the character of the foliage is clearly like that of *P. davidiana*. Some trees have failed to bloom. Certain seedling trees grow compactly and have an excessive amount of dark green foliage. The foliage of some of these seedling trees is markedly resistant to *Bacterium pruni*. Several thousand open-pollinated seeds of the peach x *P. davidiana* crosses were planted in the spring of 1940. Their germination was high and the seedling trees, in nearly all lots, made a remarkably strong growth. These interspecific hybrid seedlings may have value as stocks because they have shown hardiness which is superior to that of ordinary peach seedlings. The average height of these seedlings at the end of the growing season was 42 inches, as compared with ordinary peach seedlings which averaged 30 to 36 inches.

There is little evidence that real hardiness is to be found by simply crossing standard varieties of the peach. Under Iowa conditions at least four selections of open-pollinated third-generation seedlings of the Hill's Chili have been considerably hardier in tree than varieties like Hale and Elberta and possibly Champion. These are Polly, No. 8, No. 17 and No. 18. Open-pollinated seedlings of No. 8, No. 17 and No. 18, which were planted in the orchard in 1937, produced an overload of fruit in 1939 and also set an abundance of fruit buds.

A few years ago our attention was called to a peach which was grown on a farm near Boone, Nebraska from generation to generation by seeds. A small amount of seed of this strain of peaches was secured in 1935. The seeds were germinated in 1936 and the trees were planted in the orchard in 1938. All of these trees fruited in 1939, and in 1940 they produced a full crop. The trees are all very similar in foliage and habit of growth. Their freestone fruits are also similar, differing somewhat in season of ripening and in quality. All are about 1¾ to 2 inches in diameter, round in form, the skin color is pale yellow or white with a blush. Their flesh is white, somewhat fibrous, medium

juicy and of fair quality. These trees bloom late; approximately 1 or 2 days earlier than mid-season for the apples in this locality.

On January 18, 1940 the temperature at Ames was recorded at —25 degrees F. During February an examination was made to determine fruit bud survival on each of 105 seedling peach trees. The Boone seedlings had 30 per cent to 65 per cent survival, which is considerably higher than in any other line of seedlings. These trees bloomed later than any other line of peach seedlings and all set more fruit than was necessary for a full crop.

The seedling trees of No. 8, No. 17 and No. 18 also were surprisingly high in fruit bud survival. Two seedling trees of No. 8 showed 45 to 55 per cent live buds. Ten seedling trees of No. 17 showed a survival ranging from 15 to 45 per cent and nine of these trees set a good crop of fruit; five were overloaded. Fifteen seedling trees of No. 18 showed bud survival ranging from 15 to 55 per cent, two trees set a fair crop and 13 were well loaded. The time of blossoming of the seedlings of No. 17 and No. 18 is nearly as late as that of the Boone seedlings. The fruits of the seedlings of No. 8, No. 17 and No. 18 have a deep yellow under-color which is overspread by dark red which often extends over one-half to three-fourths of the surface. All are yellow fleshed and several rate good quality and nearly all are freestone.

Fruit bud survival in nearly all the *Prunus davidiana* seedlings was low; although several crosses showed trees with 15 per cent live buds, one tree had 45 per cent bud survival.

Those trees with a high percentage of live buds were crossed in 1940 with varieties, the pollen of which was supplied through the courtesy of the United States Horticultural Field Station, Beltsville, Maryland. Crosses were also made with pollen of selected seedlings. A total of 32 crosses was made on 12 different trees. Pollen from 10 varieties and seedlings were used. The number of seeds secured was 1,277.

On November 11, 1940 while peaches were still in full leaf, the temperature dropped rapidly to below zero and remained around 4 degrees F for four days. An examination of the bark on the trunks and lower limbs indicates that the peach seedlings have sustained severe damage. A few may survive. In general, the trees of the peach x *Prunus davidiana* crosses show relatively little injury as compared to other lines of seedlings. This indicates that *P. davidiana* carries and transmits those factors which produce hardiness of tree and suggests the value of continuing this line of experimental breeding to determine whether, in succeeding generations, a new and hardy race of peaches may be secured. Crosses have been made between selected seedlings of this line and selected seedlings of the No. 8, No. 17 and No. 18 for the purpose of determining whether hardiness of tree and hardiness of fruit bud may be combined.

The Starch Cycle in the Hachiya Persimmon

By C. J. Archer, *University of California, Los Angeles, Calif.*

THIS paper reports a study of the starch content of Hachiya persimmon trees made between November, 1938 and May, 1940. The trees used for the study were four normal, fruiting trees in addition to one tree from which the vegetative buds were removed the first week in March, 1939, one tree from which the flower buds were removed on April 14, 1939, and one tree from which the young fruits were removed on June 9, 1939. Previous season's shoots, second year, and third year branches were collected weekly between November 10, 1938 and November 11, 1939 from the normal trees and bi-weekly during the growing season of 1939 from all other trees. The samples were preserved in 50 per cent alcohol; subsequently, they were sectioned, stained with IKI, mounted in 50 per cent glycerine, and studied microscopically for starch content. A more detailed account of the trees and the collection of samples was presented in a previous paper (1).

All slides (50 to 52) of each year's growth from the normal trees were laid out in a series according to the density of color without regard to date of sample. Consecutive numbers from 0 to 50 or 52 were assigned each slide according to its position from the lighter end. Subsequently, numbers of slides were plotted against dates appearing thereon to obtain the curves appearing in Fig. 1. Curves for all other series were obtained by matching slides with those of the same age branches of the normal trees, and assigning the numbers of the normal slides. Numbers assigned slides of the control series are not quantitative except insofar as they indicate how many color shades occur between slides of successive weeks.

The starch cycle in the bearing persimmon tree in the coastal district of southern California was found to be similar to those recorded for deciduous trees by other investigators. As shown in Fig. 1, the starch curve drops to a very low point about the second week in February; rises rapidly but somewhat irregularly to a maximum between the last week in March and the second week in April; drops very rapidly to a second low point from 2 weeks later in the third year branches to 10 weeks later in the previous season's shoots; rises slowly in irregular waves until approximately the first or second week in December; then drops in irregular waves to the low point in February. Fig. 1 shows the curves for one pair of bearing trees, and those for the other pair were found to be very similar. In all instances the fall maximum was found to be greater than the spring maximum, and the spring minimum was found to be lower than the winter minimum. Of some interest is the fact that when starch accumulations are plotted at weekly intervals, the curves are not as regular as those obtained by plotting less frequent observations. Several factors, one of which will be evident later, seem operating to cause significant fluctuations in the general trend. Some slight, but inconsistent, differences exist between curves of different ages of branches studied.

Curves for bark, wood, and pith were plotted and studied. During the greater part of the year, only traces of starch were found in the

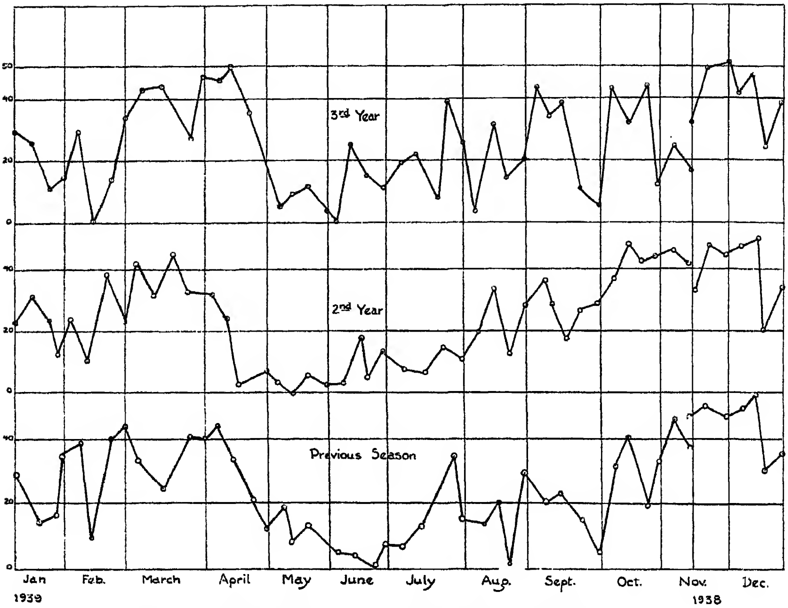

FIG. 1. Starch cycle in the Hachiya persimmon.

bark, with irregular fluctuations between small amounts and no starch. Large amounts of starch were found in the bark for two successive weeks during the spring maximum, indicating an overflow of starch into that area during the rapid accumulation period. Little or no starch was found in the phloem except during the above-mentioned maximum period, at which time it was found in the phloem parenchyma and ray cells. Curves for the fluctuations of starch in the wood and pith were very similar to those shown in Fig. 1; in fact, neither showed any significant variations from the general curve.

Careful study failed to reveal the wave-like accumulations and disappearances of starch between the three ages of branches studied or within the several tissues of the same age branches, as has been reported by several investigators working with other plants. With few exceptions, starch accumulations and disappearances occurred rather uniformly throughout the three ages of branches.

No correlation between vegetative activities and the rapid decrease in starch to the winter minimum, occurring in February, was apparent, no sign of cambial activity, described in a previous paper (1), being evident until almost March 1. The first signs of cambial activity appeared when the amount of starch present in the sections was intermediate between the winter minimum and the spring maximum. Translocation of soluble carbohydrates to the branches studied, therefore, and subsequent starch synthesis must have occurred after growth activities had begun.

The rapid decline in the amount of starch, observed between approximately March 1 and May 1 undoubtedly reflects the use of food

reserves for growth prior to the attainment of photosynthetic efficiency. During this period the formation of new wood was observed in all three ages of branches studied, new shoots up to 6 inches in length were formed, and flower buds appeared; yet, the leaves did not attain full size until the last week in April. The slow and irregular increase in amount of starch from the attainment of full size of the first leaves until leaf-fall seems to reflect the gradual increase in the ratio of the synthesis to the use of the products of photosynthesis.

Further evidence for the belief that the rapid drop in the starch curve of the normal tree in the spring is caused by growth activities was obtained in the disbudding experiment. In a tree disbudded in March, 1939, and kept free of developing buds during the balance of the growing season, the rapid decrease in starch noted in the normal tree prior to May 15 was not found, Fig. 2, curve C. Instead, the starch decreased in amount more slowly during that period and continued to decrease throughout the normal growing season, presumably due to translocation and use in respiration.

The results of a study of the effect of fruiting upon the starch cycle is shown in Fig. 2. Curves B and C show the amount of starch present in the second year branches of non-fruiting trees compared to the amounts present on the same dates in a normal tree, curve A. Since the spring minimum is reached in non-bearing trees as late or later than in bearing trees, it would appear that the activities connected with vegetative growth at that time are much more influential in decreasing the starch curve than are flowering and fruit-setting. Non-bearing trees were found to accumulate starch much more rapidly and steadily during the growing season than bearing trees. Of particular interest, however, is the fact that the accumulations of starch in non-bearing trees was relatively uniform in contrast to the cyclic accumulation in bearing trees. This would seem to indicate, since other factors were the same for bearing and non-bearing trees, that the drain upon the products of photosynthesis by the persimmon fruits was

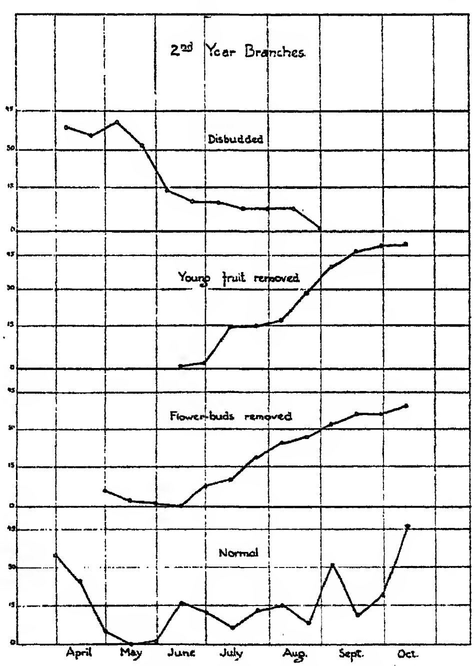

FIG. 2. Effect of fruiting upon starch cycle in the Hachiya persimmon.

cyclic rather than relatively uniform during the period of fruiting. Flowering, as well as fruit-setting, seems to suppress starch accumulation. The tree allowed to flower did not show significant starch accumulation until after the young fruit was removed, while the tree not allowed to flower showed starch accumulation 2 weeks earlier.

In summary, a study of the starch cycle in bearing and non-bearing persimmon trees in the coastal district of southern California revealed that; (a) the normal starch cycle is similar to that found in deciduous trees by other investigators; (b) no definite wave-like accumulations and disappearances of starch between the three ages of branches studied or within the several tissues of the same age branches was found; (c) the normal starch cycle was found to reflect general growth activities in the tree except during the rapid decrease to the winter minimum; (d) fruiting was found to suppress starch accumulation; and (e) evidence was obtained indicating the probability that fruit development is cyclic rather than uniform.

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Extent of Colored Area on Elberta Peaches in Relation to Leaf Area Per Fruit and to Fruit Size

By C. F. KINMAN, *U. S. Horticultural Station, Beltsville, Md.*

IN a study of the performance of Elberta peach fruits in relation to leaf area on ringed branches, observations were made to determine what percentage of the area of the fruit was covered with red. Previous work with ringed branches has been reported on the effect of leaf area on color of apples (1) and on size and chemical composition of peaches (2). The trees selected for use in this work were large and vigorous, of full-bearing age, in irrigated orchards, and all set good crops of fruit during the continuance of the experiment. The orchards are in a large commercial fruit-growing district in the lower Sierra Nevada foothills near Penryn, California. Here, days of uninterrupted sunshine are the rule from early in the peach-growing season until after harvest. Trees in three orchards were used in the experiment.

The branches that were used were about ½ to ¾ inch in diameter at the point of ringing before the bark was removed, and about 2 feet in length. They were ringed a few days after the last flower petals fell and the fruit was thinned to the ratios of one fruit to 10, 20, 30, 40, and 60 leaves. The ringed area was kept open during the season. One set, or more, of branches with all of the fruit-leaf ratios was established on each tree used in the experiment. In adjusting the fruit-leaf ratio no leaves were removed, the adjustments being affected by removal of fruit; therefore leaf shading was not a factor in causing different amounts of colored area per fruit.

The fruit was harvested when eating-ripe or very nearly so, and each fruit was weighed, measured, and an estimate recorded of the percentage of solid red area of the exposed half of the fruit.

At the completion of the harvest all leaves on experimental branches were collected and measured.

The data on the area of solid red color on fruit with different leaf areas on ringed branches that were obtained in 1933, 1935, and 1936, are combined and summarized in Table I.

TABLE I—ELBERTA PEACH COLOR IN RELATION TO LEAF AREA PER FRUIT AND TO SIZE OF FRUIT ON RINGED BRANCHES

Number of Leaves Per Fruit	Number of Fruit	Leaf Area Per Fruit (Sq In)	Average Weight of Fruit (Grams)	Area of Solid Red Color on Exposed Half of Fruit (Per Cent)
10	245	31.1	71.6	44.7
20	248	61.8	115.7	32.7
30	149	87.5	157.9	29.5
40	143	120.1	185.3	22.5
60	112	170.4	217.2	16.5

It is evident that the fruit had a much greater percentage of colored area where the leaf area was low than where it was high, and that the colored area decreased as the leaf area per fruit and the size of fruit increased. The percentage of red area was approximately one third as

great for fruits with 60 leaves as for those with only 10. The average weight of fruit however, on branches with 60 leaves per fruit was three times as great as on those with 10 leaves.

On the trees in this experiment and on neighboring trees, the fruit in the interior of the trees appeared to be about as well colored as outside fruit, but fruit enclosed in black cloth bags did not develop any red color at all on either ringed or unringed branches.

Leaves from the ringed branches used in this experiment were not analyzed, but had amounts of nitrogen and carbohydrates been determined, they might have provided a basis for explaining the wide differences in amount of color for different fruit-leaf ratios.

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A Continuous Apple Thinning Experiment Conducted From 1920 to 1939

By D. V. Fisher and R. C. Palmer, *Dominion Experimental Station, Summerland, B. C.*

THINNING of apples is a practice widely followed in commercial apple producing areas. Many short-term apple thinning experiments have been conducted but the effects of continuous thinning to a definite plan over a long period of years have not been widely studied. It is the purpose of this paper to present some data bearing on this aspect of the problem.

Eighteen trees of each of the varieties Newtown, Rome, McIntosh, and Delicious were planted at the Summerland Experimental Station in 1916. The trees were planted 30 feet apart on the square, in eight rows with nine trees in each row. There was one row of each variety in the north half, and one in the south half of the orchard. The majority of the trees commenced to bear in 1920 and a thinning experiment was then initiated. In each row, the fruit on trees 1, 4, and 7 was thinned to 9 inches apart; that on trees 2, 5, and 8 to 6 inches apart; and that on trees 3, 6, and 9 to 3 inches apart. The thinning was performed when the fruits reached a size of 1½ inches in diameter. The same thinning treatments were practised on the same trees each year. At harvest all fruits from each individual tree were sorted into four size grades: over 3 inches, 2½ to 3 inches, 2¼ to 2½ inches, and under 2¼ inches in diameter. Fruits under 2¼ inches in diameter, windfalls, and apples injured by insects, disease or limb-rubs, were classed as culls. In addition, the red-coloured varieties were sorted into three colour grades: Extra Fancy, Fancy, and Cee.

In 1937, a report (1) was issued covering the results of the experiment up to 1935. This report included a comprehensive survey of the literature. At that time no significant differences in total crop had resulted from the different thinning treatments. However, size of fruit had been increased and a slight improvement in colour had been brought about by heavier thinning, which had also tended to lessen biennial bearing and to increase tree size. The present report summarizes the results of this experiment up to and including 1939.

Results

The general trend of results has been unaltered from the previous report on this experiment issued in 1937 (1). The total yield per tree of each variety under different treatments since 1920 is given in Table I.

Table I provides significant data concerning the relative bearing capacities of the four varieties. McIntosh was the heaviest yielder followed closely by Delicious. Rome produced about two-thirds as much fruit as McIntosh, and Newtown about half as much.

The figures presented in Table I indicate that over the 20-year period the heavy and medium thinned trees produced practically the same tonnage as the lightly thinned trees. This may have been due in part to increased bearing area, but even more to increased size of fruit.

TABLE I—INFLUENCE OF DEGREE OF THINNING ON YIELD OF APPLES (1920–1939)*

Variety	Total Yield Per Tree Over 20-Year Period		
	Thinned 9 Inches (Pounds)	Thinned 6 Inches (Pounds)	Thinned 3 Inches (Pounds)
McIntosh	10314±450	10092±545	9624±429
Delicious	9378±519	9570±391	8982±470
Rome	7227±267	6755±551	6540±567
Newtown	4901±321	5037±383	5618±409

*In calculating probable errors, Bessel's formula was used.

The effect of severity of thinning upon size of fruit is shown in Table II. Heavy (9-inch) thinning has markedly increased the proportion of fruit in the over 3-inch class, and reduced the amount of small fruit.

TABLE II—INFLUENCE OF DEGREE OF THINNING ON SIZE OF APPLES (1930–1939)

Variety	Thinning Distance (Inches)	Average Yield Per Tree Per Year				
		Over 3 Inches (Pounds)	2½ to 3 Inches (Pounds)	2¼ to 2½ Inches (Pounds)	Culls (Pounds)	Total (Pounds)
McIntosh	9	373	379	14	86	852±36.5
	6	350	269	95	84	825±33.1
	3	260	317	98	85	760±33.2
Delicious	9	343	272	93	79	787±38.3
	6	279	417	43	79	818±32.8
	3	128	450	111	64	753±43.7
Rome	9	200	304	31	63	598±31.5
	6	108	333	55	55	551±38.9
	3	106	315	53	52	526±41.0
Newtown	9	68	255	44	37	404±27.1
	6	47	286	56	36	425±36.6
	3	55	267	90	48	460±36.8

The effect of thinning upon fruit colour has not been so significant as the effect upon size. This is shown in Table III. With the McIntosh variety, there were no appreciable differences in colour development

TABLE III—INFLUENCE OF DEGREE OF THINNING ON COLOUR OF APPLES (1930–1939)

Variety	Thinning Distance (Inches)	Average Yield Per Tree Per Year				
		Extra Fancy (Pounds)	Fancy (Pounds)	Cee (Pounds)	Culls (Pounds)	Total (Pounds)
McIntosh	9	354	209	203	86	852±36.5
	6	377	201	163	84	825±33.1
	3	308	201	166	85	760±33.2
Delicious	9	422	150	136	79	787±38.3
	6	456	136	147	79	818±32.8
	3	279	170	240	64	753±43.7
Rome	9	117	143	275	63	598±31.5
	6	79	125	292	55	551±38.9
	3	63	121	290	52	526±41.0

due to thinning treatment. On the other hand, with the Delicious and Rome, 9- and 6-inch thinning considerably increased the proportion of Extra Fancy apples and lowered the proportion of Cee grade.

Conclusions

The continuity of this experiment over a long period of time provides unique information on the subject of apple thinning. The results secured indicate that thinning of apples to as much as 9 inches apart can be employed without sacrifice of tonnage; that heavy (9-inch) thinning, while somewhat more expensive than light (3-inch) thinning, may be justified with varieties such as Delicious and Rome of which comparatively large sized fruit is desired; and that light thinning is preferable with varieties such as McIntosh and Newtown of which comparatively small sizes are popular on the market.

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Effect of Time and Amount of Harvesting on Alternate Bearing and Fruit Size in the Valencia Orange

By R. W. Hodgson, S. H. Cameron, and E. R. Eggers,
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In southern California citrus districts, excepting only the desert area, the Valencia orange does not mature until well after the period of bloom for the succeeding crop. In the coastal areas good quality is usually not attained before midsummer and the shipping season extends into early November. The normal situation therefore requires that during a variable, but often considerable, part of the growing season the trees carry two crops — the old crop, which is approaching maturity or being held on the trees, and the new crop, which will not reach maturity until the following season. Not uncommonly, a considerable part of a large crop will remain on the trees for 15 to 18 months during the last 3 to 5 months of which the trees are also carrying the crop for the next season.

To these facts are generally attributed the alternate bearing tendency long recognized in this variety and the rather widespread feeling that late harvesting tends to accentuate it, both of which appear to be most pronounced in the late, or coastal, areas. The belief is also general that early harvesting of part of the crop not only tends to reduce the alternate bearing tendency but also increases fruit size in that part left for later harvesting.

With a view to ascertaining the facts concerning these beliefs, a preliminary investigation was undertaken in 1936 on a group of young trees, part of a block where the taking of individual tree yield records had been started in 1933 for the purpose of studying the normal bearing behavior of this variety. The initiation of a pruning experiment in 1939, which involved cutting back alternate trees, has effectively terminated the first phase of this study, the results of which appear to justify a report at this time.

Experimental Materials and Procedures

The 50 trees employed in this study are part of a lot of 300 propagated in 1927, as described by Cameron (2), and planted in May, 1929, as year-old buds. They consist of two rows of 25 trees, the distance between rows being 20 feet and between trees 12 feet. The soil is Yolo silt loam, of high initial fertility, uniform in texture and depth, and provided with excellent drainage. The trees have grown well and have borne excellent crops and are well above average for their age. They were exceptionally uniform at the time of planting and have continued to be remarkably so ever since. Because of their rapid growth and close planting in the rows, they began to crowd at about the time the differential harvesting treatments were started. It is believed therefore that their bearing behavior during this period has been comparable to that of older and larger trees under the usual conditions of wider spacing in commercial orchards.

The differential harvesting treatments began in 1936 and consisted

of pickings at 5 periods — February 15, April 1, June 15, August 1 and September 15 — four trees being completely harvested at each period and four trees having approximately half the crop harvested at each of the five periods and the balance October 15. In addition 10 trees were given commercial harvesting practice; about half the crop was harvested when the fruit had attained good commercial quality — June to August — and the balance in October. Since the data for these trees add nothing to the comparisons they are not included in this report.

For each tree the weight of crop was recorded, the number of fruits of each packing size determined, the total number of fruits noted and the average weight per fruit calculated. Unfortunately some errors occurred both in applying the differential treatments and in recording the data; they are considered not to vitiate the general conclusions, however. Annually since 1933, when the keeping of tree yield records was begun, trunk circumference measurements have been made.

Because of the small number of trees in each treatment, statistical analysis of the data has not been employed. The method used has been to graph on one chart the behavior of each of the eight trees in any given comparison and to note the trends of the two treatments. In all cases the trends were similar at the time differential harvesting treatments were begun; in nearly all cases they were noticeably different at the conclusion of this study. The data for each treatment were then averaged and again compared. While the individual tree data show considerable variability, with very few exceptions this treatment indicated decided differences in trend by the termination of the study. The few cases in which agreement did not occur involved treatments in which harvesting errors are known to have been made or have to do with midseason treatments.

In all cases the trends of the early and late treatments were consistent. In this connection it is recognized that in these treatments there are two opposing factors; in the early treatments the additional weight the fruit would have attained had it been left on the trees, in the late treatments the unavoidable loss of fruit from pilferage and dropping. It is believed that these approximately offset each other.

In the presentation of data and conclusions which follow it is recog-

TABLE I—Average Yield (Pounds per Tree) in Differential Harvesting Treatments

Treatment	1933	1934	1935	1936	1937	1938	1939	1940
Complete Harvesting at Period Indicated								
Feb 15	60.5	55.7	102.8	255.7	13.9	398.7	222.7	491.5
Apr 1	70.0	23.0	138.5	254.2	53.2	369.5	143.7	338.0
Jun 15	58.2	39.0	140.7	260.5	6.5	391.4	93.4	439.0
Aug 1	58.0	42.2	97.7	287.7	14.5	438.0	160.7	495.0
Sep 15	48.7	30.2	112.0	238.0	7.5	367.5	73.7	190.7
Partial Harvesting, Half at Period Indicated; Balance October 15								
Feb 15	59.5	19.0	144.5	205.2	5.2	328.0	113.7	296.7
Apr 1	55.0	55.5	153.0	286.2	14.6	398.0	144.5	419.5
Jun 15	56.5	29.7	137.7	225.5	22.1	365.7	79.7	353.7
Aug 1	41.7	43.2	83.0	254.0	2.0	387.5	90.5	249.0
Sep 15	66.0	20.5	197.5	219.0	26.7	336.7	65.7	148.5

nized that a more comprehensive experiment than that here reported will be required to adequately substantiate the findings here noted. It is the present plan to undertake such an experiment at an early date.

Data and Interpretation

General Features of the Bearing Behavior:—From the data in Table I and Fig. 1, it will be observed that for the past 6 years pronounced alternation in bearing has existed. Examination of the individual graphs shows that prior to 1935 considerable numbers of the trees were in opposite stride, that all 50 were together in stride in that year, 47 in stride in 1936 and all together again in 1937, in which condition they have since remained. It would appear that conditions favorable for fruit-setting must have occurred during the spring months of 1934 and 1935, which were reflected in increase of yield in 1935 and 1936, and that these two relatively good crops in succession were sufficient to establish the alternate bearing habit in all these young trees.

Bearing Behavior as Influenced by Time of Harvesting:—From Fig. 1 it seems clear that early harvesting of the crop has resulted in higher average yields and has tended to reduce the amplitude of alternation, and this in spite of the fact that this graph includes the only treatment (June) which, for unknown reasons, is out of harmony with the others. By contrast, the late harvesting graph is considered to be abnormally high in 1940, the cause for which is believed to be the fact

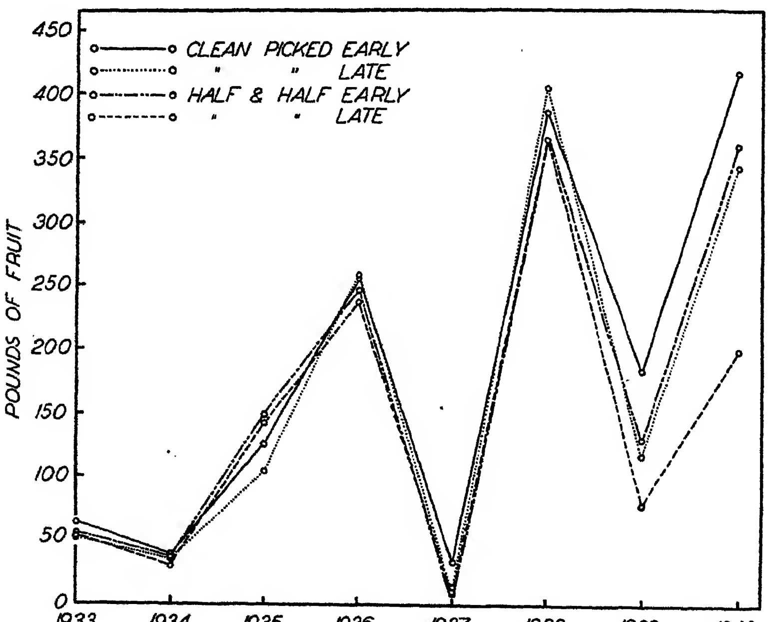

FIG. 1. Average yields of Valencia orange trees in differential harvesting experiment.

that it contains a treatment (August) in which an error in harvesting occurred in 1939, in that the crop which should have been harvested in August was picked in April. The comparison February-September shows much greater differences than are indicated in this figure. In four of the five comparisons there was complete agreement as to difference in trend.

Moreover, it is evident that the same differences in trend exist in the treatments where half the crop was harvested at the periods indicated and the remainder left on the trees until October. Here too, there was agreement in four of the five comparisons. Even the August-September comparison showed pronounced differences in trend.

Bearing Behavior as Influenced by Amount of Crop Harvested:—Fig. 1 also seems to indicate that harvesting all the crop, either early or late, has resulted in greater increase in average yield than harvesting half the crop at comparable periods and leaving the balance until late in the season. In this comparison, however, the effect on amplitude of alternation is not consistent, the reason for which is believed to be the fact, previously mentioned, that the late harvesting graph is abnormally high in 1940. There was agreement in four of five comparisons.

Tree Growth as Related to Time of Harvesting:—The results presented thus far seem to indicate a depressing effect of a large crop on the amount of fruit in the succeeding crop, which effect increases with the length of time the fruit is allowed to remain on the tree. It has previously been noted that during on-crop seasons the trees make less new growth and carry fewer leaves than in off-crop seasons (2, 6), a possible reason for which is the continued intake of nitrogen by the fruit so long as it remains on the tree (1). It has seemed to us, though quantitative data are not now available, that these relationships are less marked in the early harvested trees. That they have grown somewhat faster than the late harvested trees since the differential treatments were begun is suggested by the graphs in Fig. 2. This is considered to support the general conclusion previously noted.

Size of fruit:—Table II summarizes the data available for the complete harvesting treatments and Fig. 3 depicts the relationships which seem to exist.

Considering first the general trends and relationships, it will be noted that increase in the number of fruits per tree has occurred more rapidly than increase in weight of crop, with the result that both median packing size and average weight per fruit have tended to

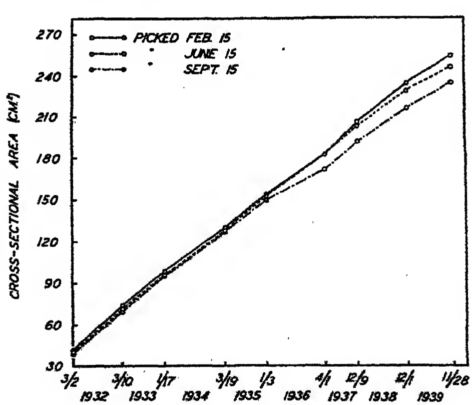

Fig. 2. Average trunk cross-sectional areas in differential harvesting experiment.

TABLE II—AVERAGE WEIGHT OF CROP, NUMBER OF FRUITS, MEDIAN PACKING SIZE AND WEIGHT PER FRUIT FOR DIFFERENTIAL HARVESTING TREATMENTS

Item	1936	1937	1938	1939	1940
		Harvested June 15			
Weight of crop	260.5	6.5	391.4	93.4	439.0
Number of fruits	795.0	21.0	1410.0	255.5	1937.0
Median packing size	252	252	324	252	324
Average weight per fruit	5.24	5.35	4.43	5.84	3.63
		Harvested August 1			
Weight of crop	278.7	14.5	438.0	160.7	495.0
Number of fruits	778.7	47.2	1343.0	556.0	1940.0
Median packing size	216	216	216	252	288
Average weight per fruit	5.74	4.83	5.21	4.92	4.07
		Harvested September 15			
Weight of crop	238.0	7.5	367.5	73.7	190.7
Number of fruits	695.7	35.2	1216.2	244.0	768.5
Median packing size	216	288	216	288	324
Average weight per fruit	4.96	3.67	4.82	4.87	3.98

decrease, particularly in the 1940 crop. We are unable to find any consistent relationship between number of fruits or weight of crop per tree and median packing size or average weight per fruit. Thus the highest average weights per fruit occurred in 1936 and 1939, on-crop and off-crop years respectively, whereas in 1937 and 1938, off-crop and on-crop years respectively, the average weight per fruit was the same and was smaller. In 1940, an on-crop year, it was smallest, apparently because of the much larger number of fruits in relation to the weight of crop.

In the complete harvested treatments (data not shown), with one exception, average weight per fruit increased as the season progressed and, likewise with one exception, the same trend occurred in the treatments where half the crop was harvested at comparable periods and the balance in October. No fruit-thinning effect was noted in the October picking, however, one reason for which may be the fact which the data clearly show, namely that the first pickings consisted mainly of the larger fruits.

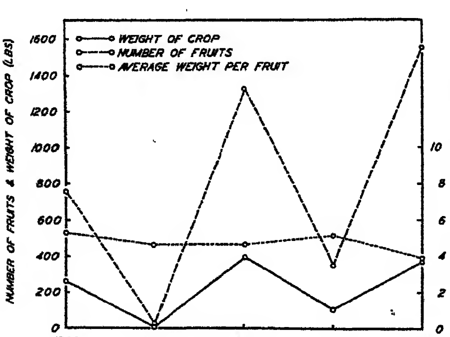

FIG. 3. Average weight of crop, number of fruits per tree and weight per fruit in differential harvesting experiment.

Analysis of the data fails to indicate relationships of any kind between time of harvesting or amount of crop harvested in a given crop and size of fruit in the succeeding crop.

DISCUSSION

In comparing our results with those of other workers on the same or similar materials, it should be pointed out that our treatments were

applied after the fruit was substantially mature, at periods much later than ordinary fruit-thinning. Thus at the time of our earliest treatment, February 15, the fruit was 9 or 10 months old and it was only 2 or 3 months until the period of bloom for the next crop. Increase in size of fruit in the current crop, from partial harvesting, was hardly to be expected. Our results are in agreement on this point with those of Waynick (4) who found that removal of about half the Valencia orange crop at the beginning of the harvesting season did not increase the growth of the fruit left.

Several investigators have reported effects on the succeeding crop resulting from fruit-thinning or differential harvesting of the preceding crop. Parker (3) found, with both the Washington navel and Valencia varieties, that fruit-thinning was followed, in the next crop, by an increased number of fruits and a greater total volume, but smaller mean size. West and Barnard (5) obtained similar results from fruit-thinning, which were even more pronounced when all the crop was removed at the time of normal fruit-thinning. More comparable to our experiment, however, were their early, normal and late harvesting treatments (6). Complete agreement exists for the early and normal harvesting treatments but apparently not for the late harvesting treatment which, in their experiment, did not affect the number of fruits harvested the following season but did slightly decrease their size. In our experiment late harvesting rather consistently seems to have reduced the weight of crop the following season but we are unable to find any consistent relation to number or size of fruits.

In this connection, mention should also be made of the fact that, whereas they report the production of large fruit of inferior quality in the off-crop years and of small fruit in heavy-crop years, our data suggest such a relationship for only 2 of the 5 years under study, namely 1939 and 1940.

Conclusions

It is believed that the data obtained in this preliminary experiment support the following tentative conclusions:

(a) In southern California coastal districts the Valencia orange tree exhibits a marked alternate bearing tendency. (b) The heavy crops normally produced in the on-crop years depress tree growth during the current season and yield in the following crop. (c) The depressing effects on tree growth and ensuing crop may be reduced by early harvesting; lightening the crop produces a similar effect on amount of fruit in the ensuing crop. (d) No consistent relationship exists between fruit size or weight and amount of crop.

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A Simple Method of Making Tree Injections

By W. H. Friend, *Agricultural Experiment Station, A. and M. College of Texas, Weslaco, Tex.*

THE idea of inducing growing plants to take dissolved chemical substances into their vascular systems is nothing new. As early as 1735 Dr. S. Hale recommended the injection method of treating standing timber to the British Admiralty (2). Later the plant scientists Saussure and Boucherie demonstrated that plants could be induced to take considerable quantities of certain "toxic" salts such as copper sulphate into their water conducting system (4). Within comparatively recent times, investigators such as Rumbold (3) and Craighead and St. George (1) have shown that the injection method can be used successfully in combating certain specific diseases and insects.

This paper is not primarily concerned with the efficiency of the injection method in combating disease but is intended to call the attention of plant scientists to a simple but effective method that utilizes inexpensive, corrosion resistant equipment that is easily set up. Because of its simplicity and low cost, hundreds of individual trees could be placed under treatment at one time.

By accident it was discovered that a citrus tree affected with internal dry rot could be made to absorb appreciable quantities of a 1 per cent copper sulphate solution, to its obvious benefit. The marked improvement in the condition of this treated tree encouraged the writer to repeat the experiment with a large number of individuals. This enlargement of the scope of the work called for a simple and inexpensive method, that could be used in practice, provided the injection method gave the desired results.

Development of the Method

Many schemes have been devised for introducing soluble chemical substances into the tissues of living plants in such a manner that they can be readily taken up by the cell sap and transported to certain parts of the plant structure. These methods vary from the rather crude technique of placing pulverized chemical into auger holes and sealing up the wounds (2) to the rather ingenious, continuous, drip method of treating girdled trees devised by Craighead and St. George (1).

The method used in this test might be called the "fountain syringe" method of making tree injections, except for the fact that large bore rubber tubes (garden hose) about 3 feet long are substituted for the conventional type of fountain syringes. Shorter lengths of hose could be used, but the longer lengths increase hydrostatic pressure and do not require refilling quite so often. The large holes required for insertion of standard ⅝ inch garden hose also tends to increase the rate at which the plant "takes its medicine", as compared with the hypodermic needle method.

The auger bits used in making the holes into the trunks or limbs of the trees should be slightly smaller than the outside diameter of the rubber hose, as this insures leak-proof insertions. The 3-foot lengths

of hose can be tied to lath stakes or to trunk or limbs of the trees in such a manner that the free end is 2 feet or more above the point of insertion. The number of holes per tree and the depth of the holes must be governed by attendant circumstances. Large trees may require injections at several points, and trees infected with the facultative parasite responsible for dry root gum disease may require one or more deep borings to insure complete impregnation of the dead and infected tissues in the heart wood of the tree with the sterilizing agent. In treating small plants affected with nutritional diseases, such as chlorosis or gummosis, a single injection is all that is needed.

In the treatment of trees affected with heart rot, materials such as plant safe carbolineum, zinc chloride, copper sulphate, and sodium ethyl mercuric thio salicylate were used. Since iron, zinc, and copper are the minor elements most likely to be responsible for little leaf disease and chlorosis of citrus trees in the Lower Rio Grande Valley, water soluble salts of these metals were used in the preliminary toxicity tests.

Discussion of Results

This paper is concerned with the results obtained from the use of various materials only as an indication of the plant response from the injection treatment made according to this simplified method. Copper sulphate, in 1 per cent aqueous solutions, seemed to produce the greatest response from grapefruit trees affected with "little leaf" disease, while comparable strengths of zinc chloride solutions brought about the greatest improvement in foliage coloration in the case of Temple orange trees affected with chlorosis.

An entirely satisfactory method of measuring the efficiency of the treatments designed to check the spread of the weakly parasitic fungus responsible for internal dry rot of citrus trees has not been developed. The final recovery of the treated trees from the gummosis caused by heart rot fungus will be proof of the value of the treatment, provided it can be shown by "post mortem" that all dead and diseased tissues were thoroughly impregnated with the fungicide.

It is realized that the results herein reported may hold true only for the species of citrus used in these tests and that the results may be entirely different under less favorable environmental conditions. Since the method is simple and utilizes inexpensive equipment, it might be used by other investigators.

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An Inexpensive Homemade Scale for Weighing Fruit[1]

By R. L. McMunn, *University of Illinois, Urbana, Ill.*

WITH many orchard experiments in which the fruits are involved, it is essential that either the weight or the size be secured. Sizing the fruit over most graders is generally not accurate enough with many experiments; therefore, the weight of individual fruits is often secured. Unfortunately, weighing individual fruits is very time consuming, because there is no inexpensive self-recording scale on the market. Such being the case, eight semi-self-recording scales were made this past summer and used in securing the individual weights of more than 100,000 fruits. Since this scale proved so satisfactory and can be built in about one day at a cost not exceeding $2.00, the details are being passed along with the thought that they will be found useful to others.

The scale, set up for weighing, is shown in Fig. 1. The details of construction and operation are given in the following paragraphs.

The scale, with dimensions, is illustrated by a line drawing in Fig. 2. To the base (F) are fastened securely wooden uprights A, B, C and D. Piece E is used as a carrying handle, as well as a brace to keep the uprights rigid. Slot X and a semicircular channel (Y) are cut in the top of upright D. The scale beam (T) swings in slot X. Rod GG on which the scale beam rotates rests in channel Y. Channel Y should be parallel with the inside edge of piece D. The two pieces lettered P are made of thin sheet tin. Pieces G, H, I and J extending the full length of the uprights should be well sanded and waxed on the surfaces that form the channel in which the recording board (L) slides. Pieces H and G should be set a full ¼ inch from I and J. Strip K, used to keep the recording board (L) tight against upright D, is made of ¼-inch hard Masonite board. Four ¼-inch compression springs (Z) are set in holes in upright A to furnish pressure on strip K. The small block (FF) should be placed high enough on upright D so that the

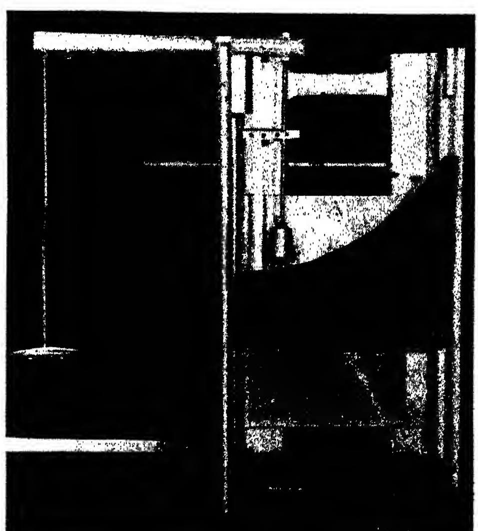

Fig. 1. Scale set up for weighing.

[1]Assistance in testing the scales and later in using them to weigh fruit was furnished by personnel of Works Progress Administration Official Project No. 665-54-3-405 (12).

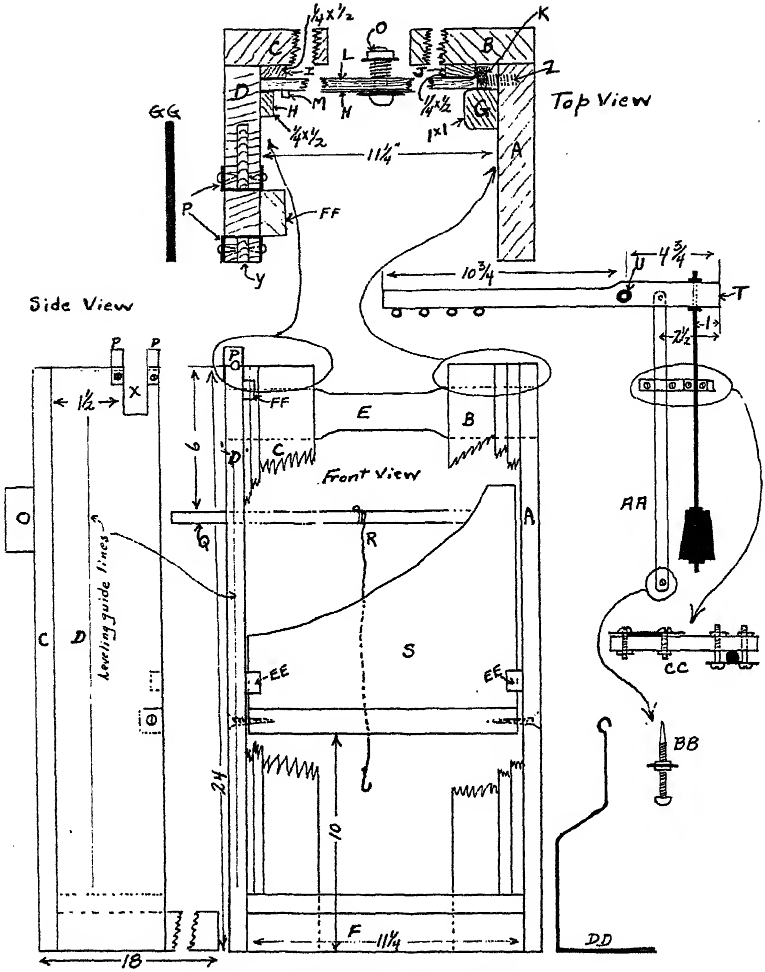

FIG. 2. Details for a homemade scale.

scale beam (T) will rest on it when in the normal position, without letting the recording arm (AA) touch upright D. It is best to set this block after all other parts are assembled.

The recording board (L), 12½ by 11 inches, is made of ¼-inch plywood. Piece M should be parallel with the left edge of the board. A piece of light weight tin (N), 12½ by 9 inches, is fastened to the board, the left edge being flush with piece M. The assembly O, which is shown in the top view of Fig. 1, is for holding the paper on the recording board (L). Another such assembly is placed at the bottom of the recording board at a distance of 11¼ inches from the one in the upper end of the recording board. These assemblies are made with a

⅛-inch stove bolt to which is soldered a washer. On the back side of the board, a small spring is placed over the bolt to hold the washer tight against the tin. A leather or felt washer is glued to the washer, so that the paper will be held firmly. A small screw eye is placed in the back of the recording board near the bottom. The hook on twine R is fastened in this screw eye.

The scale beam (T), 1 inch square, is made from hardwood. Piece U is a ¾-inch length of hard glass tubing pressed into the hole in the scale beam. (Several of these were kept on hand for replacement if any cracked or broke.) The internal diameter of the tubing should be just slightly larger than the rod (GG) on which it rotates. The recording arm (AA) is a 12-inch hack saw blade carrying a recording point (BB) made from a small bolt ground to a rounded point. The saw blade is held rigid by the assembly shown at CC.

The balance weight, made of lead, can be adjusted by adding iron washers. With our scale, weights close to 350 grams were used. Since each scale has to be calibrated, it is not necessary to have the balance weights the same on different scales.

Piece Q is a length of ½-inch dowell pin to which is fastened a piece of strong twine (R) carrying a small hook at the free end. The top of a No. 3 tin can (DD) is used as the weighing pan. Board S is used to press against the recording pin (BB) when fruit is being weighed. This board should swing freely to facilitate recording the weights. Pieces EE are to keep board S from falling too far away from the recording pin (BB).

For accurate weighing it is essential that the scale be level. When several scales are in use in the field, it is not practical to carry several levels. Such being the case, the scale is leveled in the laboratory; then, using the level in a vertical position, a guide line is drawn on the edge of upright D and another on the outside face of D. In the field these lines are used as guides in leveling the scale by the use of a small plumb bob.

It is also necessary to make a weight guide from which rulings can be made across the paper on which the weights of the fruits have been recorded. Such a guide is made by placing known weights on the scale pan and recording each on a piece of paper that has been placed on the recording board as outlined in the following paragraph. For example, if weight classes varying by 25-gram units are desired, 25-, 50-, 75-, etc. gram weights are placed in the pan and each weight recorded on the paper. The paper is removed and lines drawn through the dots, parallel with the left edge of the paper. The paper is fastened to a small board and, at the points where the lines cross the paper, small brads are driven into the board. This board can be placed at the end of a record sheet and, from the weight points, parallel lines can be drawn across the record sheet. A count of the dots between the lines is the number of fruits falling in the various weight classes.

The operation of the scale is as follows: between two pieces of 8½- by 11-inch paper, insert a piece of carbon paper. Place the paper on the recording board (L) flush against piece M and hold in place with assemblies O. Slide the board down the channels I-H and J-G to the

bottom of the scale. Fasten the hook in the screw eye at the bottom of the record board. When a fruit is placed on the scale pan, the recording arm (AA) swings in an arc across the paper. After the arm comes to rest, board S is given a light tap; this presses the recording pin (BB) against the paper and records the weight as a dot on the second sheet of paper. After several fruits are weighed, the record board is raised by turning the dowell pin, and another lot is weighed. Plot, tree number, and other pertinent data should be recorded on the paper along with the scale number if more than one scale is being used. The record sheets are accumulated to be ruled later and counts made of the fruits in the different weight classes.

With a 350-gram balance weight and the scale pan hanging from the farthest screw eye on the beam, fruits up to about 300 grams can be recorded on the paper. In the drawing (Fig. 2), it will be noted that there are four screw eyes shown on the scale beam. These can be used when very heavy fruits are being weighed. With the pan hanging from the position nearest the balance weight, a maximum of about 550 grams can be recorded. With this setting, the scale does not start to register until about 90 grams are applied to the pan. Guides, however, have to be made for each of the various positions from which the pan is hung.

Boron in Pecan Nutrition

By G. H. Blackmon, *University of Florida Agricultural Experiment Station, Gainesville, Fla.*

IN 1931 and 1932 attempts were made to grow pecan seedling trees, without aeration, in nutrient solutions of several different concentrations. The trees failed to develop properly in any of the nutrient solutions; the shoot growth became stunted and the roots soon died, although the tops might remain green and retain their leaves for long periods. Following these trials, boron was added to a part of the nutrient solutions at the rate of 4 parts per million. The trees in these solutions responded and made marked improvement in growth, but later they showed symptoms of boron toxicity. The subsequent nutrient solutions used contained ½ part per million of boron and the seedlings apparently recovered. This indicated response of pecans to boron resulted in the experiment here reported.

Materials and Methods

A series of sand and soil cultures were set up in 1934 to study the effects of boron on the nitrate absorption and growth of pecan seedlings. Clean builders' sand was used for the sand cultures and Norfolk loamy fine sand for the soil cultures. Twelve 6-gallon glazed earthen jars with drainage provided at the bottom of each were used as containers for the cultures; six for sand and six for soil. Seedling pecans which had been started from nuts (Mooré variety) germinated in clean builders' sand were transplanted to each of the jars in the spring. To three jars of each of the sand and soil series ½ part per million of boron as boric acid was applied with each application of nutrients, while three jars of each series received the same nutrients except boron was omitted.

The nutrient solutions were made up with distilled water and contained the following concentrations expressed in parts per million: NO_3, 305.0; PO_4, 601.5; K, 325.7; Ca, 58.5; Mg, 288.0, and SO_4, 1138.0. One liter of this nutrient solution was applied to each jar every 2 weeks during the growing season and distilled water added in each alternate week to keep the sand and soil moist. Iron as ferrous sulfate was added weekly in sufficient quantities to meet the requirements of the plants.

Results

Leachings:—Leachings from both culture series were collected during the growing season between nutrient solution renewal dates and the nitrates in parts per million determined for each. Both sand and soil cultures that received boron in the nutrient solution leached less nitrates during the growing period of the seedlings than did those in which boron was omitted. The differences between the boron and no boron treatments were about the same for the two cultures when they are calculated on a percentage basis. Based on the quantity of nitrates in the leachings from the two cultures, it would seem that the pecan

TABLE I—INFLUENCE OF BORON ON PECAN SEEDLINGS GROWN IN SAND AND SOIL CULTURES OTHERWISE RECEIVING THE SAME NUTRIENT SOLUTION

Cultures	Total NO_3 Leached May to Oct 1934 (Ppm)	Seedlings (Dormant)				
		Weights, Each Seedling Oven-dry (Average)			Total Nitrogen, Dry Weight	
		Tops (Grams)	Roots (Grams)	Whole Plant (Grams)	Tops (Per Cent)	Roots (Per Cent)
Sand						
Boron ½ ppm........	308	2.3	12.5	14.8	0.57	1.22
No Boron............	441	1.6	9.6	11.2	0.74	1.22
Soil						
Boron ½ ppm........	451	1.0	3.2	4.2	0.71	1.23
No Boron............	670	0.4	1.2	1.6	0.73	1.47

seedlings grown with boron in the nutrient solution absorbed more nitrates than did those which were grown without boron. The total nitrates recovered in all leachings were less from the sand cultures than they were from the corresponding soil cultures receiving the same treatments. These data are presented in Table I.

Seedlings:—Pecan seedlings generally grow rather slowly, but throughout the period of growth in the 1 year of this experiment, the trees receiving boron appeared to be somewhat more vigorous than those without boron. At the end of the experiment, the dormant seedlings were removed from the cultures, washed clean, dried in the oven and weighed. The tops and roots were weighed separately to obtain the amount of growth for each as well as the total weight of the trees. The percentages of total nitrogen in the tops and roots were then determined.

In Table I, it will be noted that the trees grown in sand had a larger total average dry weight than those grown in soil. In both cultures the weights of tops and roots separately were each heavier where boron was added to the nutrient solutions applied. The differences between boron and no boron in the growth of tops and roots were greatest in the trees grown in soil, although they made much less growth than did those grown in sand.

Data for the total nitrogen, in per cent of the dry material in the tops and roots of the trees grown with and without boron in the nutrient solutions are given in Table I. These data indicate that the percentage of total nitrogen was higher in the tops of the seedlings grown without boron in both cultures than it was in those grown with boron. The percentages of total nitrogen were the same in the roots of the trees grown in the sand culture but in the soil culture the nitrogen content was higher in the roots to which no boron was applied. The data obtained seem to show that boron is necessary in the nutrient solution for pecans when grown in cultures comparable to those used in this experiment.

Nitrogen Content of Dormant Pecan Twigs[1]

By G. H. BLACKMON, *University of Florida Agricultural Experiment Station, Gainesville, Fla.*

NITROGEN is an important element in pecan nutrition and in Florida orchards it must be supplied in adequate quantities along with phosphoric acid and potash in the orchard maintenance program. It can be supplied either in commercial forms or in leguminous cover-crops grown and returned to the soil or by both. Experiments conducted in bearing orchards over a period of years by the Florida Agricultural Experiment Station definitely show the value of adequate nitrogen and the beneficial effects of organic matter in pecan soils.

MATERIALS AND METHODS

In 1937 studies were begun on the nitrogen content of dormant 1-year twigs grown on bearing trees in cooperative experiments. The varieties used included Moneymaker, Moore, Frotscher and Stuart in Jefferson County and Curtis and Kennedy in Bradford County. The twig samples were cut in January of each year from the outer portions of branches located in uniform positions approximately half-way between the lowest and topmost parts of the trees. The material was brought to the laboratory, dried and stored in air-tight glass containers until analyzed for nitrogen.

Representative trees of known performance in the various blocks under several treatments in Jefferson and Bradford Counties were selected from which the material was taken for nitrogen determinations. The soil treatments consisted of the following fertilizer applications and cover-crop practices:

1. Nitrogen, phosphoric acid and potash (NPK) applied in spring.
2. NPK and legume, PK applied for growth of Augusta vetch (*Vicia angustifolia*) which was returned to the soil, and N applied in summer.
3. NPK + N, NPK applied in spring, supplemented with N in summer.
4. PK and legume, applied same as the PK in 2.
5. N applied in spring.
6. N + N, N applied as in 5 supplemented with N in summer.
7. NP applied in spring.
8. NP + N, NP applied as in 7, supplemented with N in summer.

The nitrogen in spring applications was derived from nitrate of soda, sulfate of ammonia and cottonseed meal, and in the summer from sulfate of ammonia. Superphosphate and sulfate of potash supplied the phosphoric acid and potash respectively.

RESULTS

The data are presented in Table I and it will be noted that the percentages of total nitrogen in the twigs were as high or higher for a particular variety where either leguminous cover-crops were grown or

[1]Harding Peterson and Erle Wirt, Student Assistants, rendered valuable aid.

TABLE I—NITROGEN CONTENT OF DORMANT ONE-YEAR TWIGS CUT FROM BEARING PECAN TREES (AVERAGE ANNUALLY FOR FOUR YEARS, JANUARY, 1937 TO JANUARY, 1940)

Variety	Kind of Fertilizer Applied							
	NPK	NPK*	NPK+N	PK*	N	N+N	NP	NP+N
	Total Nitrogen in Twigs as Per Cent of Dry Weights							
Frotscher	0.96	1.12	—	1.09	—	—	—	—
Stuart	0.90	0.88	—	0.90	—	—	—	—
Moore	0.89	0.98	0.90	0.98	—	0.97	0.98	0.93
Moneymaker	0.89	—	0.91	—	—	0.88	—	—
Curtis	0.86	—	0.90	—	0.78	0.84	—	—
Kennedy	0.82	—	0.91	—	0.89	0.90	—	—

*Average of 1.76 tons per acre (oven-dry basis) of Augusta vetch grown and returned to the soil annually in these blocks.

commercial nitrogen applied or both practices carried out in the program. The Frotscher variety showed a higher nitrogen content in the twigs where the cover-crops of legumes were grown and returned to the soil, and the twigs from the trees in the NPK and PK legume blocks had the highest nitrogen content of any of the varieties sampled. The nitrogen content of the Stuart twigs were somewhat lower than that of the Frotscher for all treatments.

The twigs from the Moore trees in general showed a somewhat higher percentage of total nitrogen in the NPK and PK fertilized legume blocks and the N + N and NP treatments. Lower nitrogen contents for this variety were found in the material cut from trees in NPK, NPK + N and NP + N treatments. Twigs from the Moneymaker trees showed about the same nitrogen percentages in all three treatments.

The Curtis and Kennedy trees are located in an experiment in which NPK mixtures with and without extra nitrogenous fertilizers applied in the summer are being compared with a commercial nitrogenous mixture in spring with one supplemented by additional nitrogen applied in summer. From the data presented in Table I, it will be seen that the twigs from the Curtis and Kennedy trees where sulfate of ammonia was applied in summer contained somewhat more nitrogen than for corresponding NPK and N treatments. The Curtis trees which received the nitrogenous mixture as the N applications in the spring produced twigs with an average of 0.78 per cent total nitrogen, which was the lowest for all the varieties sampled.

Rooting Pecan Stem Tissue by Layering

By ATHERTON C. GOSSARD, *U. S. Department of Agriculture, Meridian, Miss.*

ALTHOUGH it has been known for many years that it is possible to produce roots from pecan stem tissue, this has been difficult to accomplish, and there has been no practicable method of establishing desirable pecan varieties on their own roots either for the possible advantages of own-rooted trees in themselves or for the production of understocks. By the use of hormones, Stoutmeyer (1) has succeeded in obtaining a limited production of roots by pecan cuttings, but the producing of scion roots in quantity by some practical method has not previously been accomplished.

The author has been able to produce roots from pecan stems with considerable success by trench layering the tops of grafted or budded nursery trees, and by air layering shoots of older trees in marcot boxes, in conjunction with indole-butyric acid treatment by the toothpick method of Romberg and Smith (2). Toothpicks prepared according to their method were inserted in holes drilled radially across the greatest diameter of the stems, and the protruding ends were broken off outside, so that each stem received 1 milligram of indole-butyric acid per inch of diameter at the place of treatment. The air-layered shoots received one toothpick treatment each, and the trench-layered

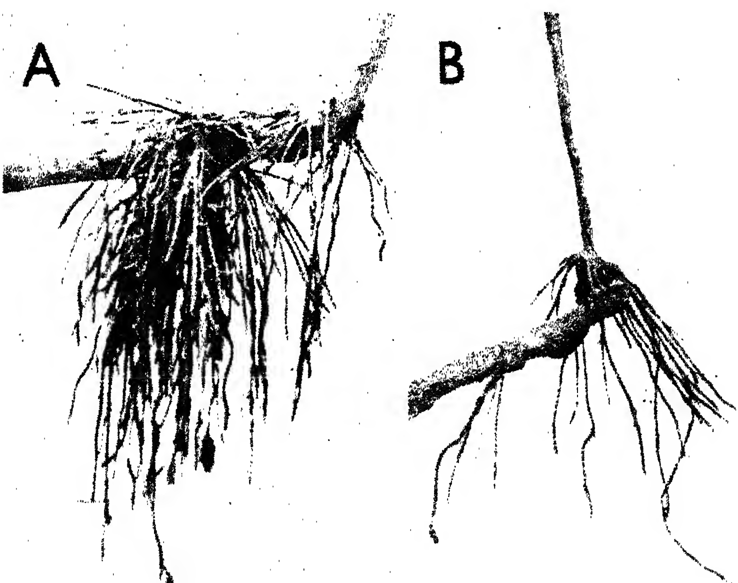

FIG. 1. A, characteristic rooting of the 1-year-old trench layered top; B, characteristic rooting of current season's trench layered top.

FIG. 2. Characteristic rooting of air-layered pecan shoot.

tops, two each about 2 inches apart—one in old and one in new wood. The rooting on one of the 1-year-old trench-layered tops, on one of a current season's trench-layered top, and on an air-layered shoot, all of the Moore variety, is shown in Fig. 1A, Fig. 1B, and Fig. 2, respectively.

The best results were obtained on stems that were layered several weeks prior to the hormone treatment. This was apparently due to etiolation, as wrapping the shoots to be air-layered with black friction tape after the method of Gardner (3) produced about as good results as did the application of the marcot boxes the same length of time prior to treatment with indolebutyric acid. Apparently the best conditions for root production are brought about by the combination of etiolation, moisture, a rooting medium, and a root-inducing substance.

Although this work has been done only on small numbers of trees and shoots and has not yet progressed far enough to determine the practicability of these layering methods for establishing pecan trees on their own roots, it is thought the constancy and quantity of root production justify a report at this time.

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Preliminary Experiments on Pruning and Training of One-Year Seedling Tung Trees

By JOHN H. PAINTER and RALPH H. SHARPE, *U. S. Department of Agriculture, Cairo, Ga.*

THE trees in American tung orchards have received very little training. In some of the first plantings, whips were set out without any pruning whatever. In later plantings, the nursery trees were cut back to "stumps" 8 inches to 18 inches high, and then left without further pruning. This produced a very low headed vase form tree, known among tung growers as a "multiple trunk" or "bush" tree. The branches are crowded and form rather narrow angles with the trunk, yet in trees up to 13 years of age, surprisingly little breakage has occurred. Another method which has become very popular in recent years is to cut back the tree severely following transplanting and allow only one bud to develop from the stump. This results in a single trunk, which, under favorable circumstances, will form what is known as a natural "crown" (Fig. 1). The tree forms this crown when, due to internal physiological causes, the terminal practically ceases growth and loses its dominance over the lateral buds, several of which simultaneously produce branches.

The height at which crowning takes place is inherent in the individual seedling, but it is influenced to a considerable extent by environment. Thus, in a heavily fertilized nursery row at Bogalusa, Louisiana, a clone known as F-542 crowned at a mean height of 194 centimeters. When transplanted to the orchard, the average height of crown for 22 of these same trees was 123 centimeters. Under conditions unfavorable for vigorous growth, a given tree will crown much lower than under favorable conditions or may even fail to crown at all. Thus, the height of a natural crown may vary considerably, due to seasonal factors which are beyond the grower's control.

FIG. 1. Two-year-old spot-planted seedling showing natural crown at 2½ feet during first season's growth.

A number of growers prefer to plant seed directly in the field instead of using nursery stock. These trees develop single trunks and form crowns in much the same manner as transplanted nursery trees cut back and trained to a single

stem. Due to slow germination of the seed, however, a considerable proportion of these so-called "spot planted" seedlings may fail to crown the first year. Observations in tung orchards throughout the Gulf States indicate these practices result in a high percentage of structurally weak trees. Trees that fail to crown the first year are especially undesirable since when they do crown, the branches are at a central point on the trunk forming a "cartwheel" or whorl of limbs. The work reported in this paper was undertaken to determine whether it is possible to develop better trees by some method of training.

Work was begun at Lloyd, Florida in a large orchard of "spot planted" seedlings, the open pollinated progeny of a single tree. From seed planted in February, these trees attained a mean height of about 100 centimeters during the season of 1939 but more than 80 per cent failed to crown. Only uncrowned trees were used. In early February, 1940, the following treatments were set up:

A. Control, no pruning or training.
B. Cut back to 24 inches, allowing one bud to develop.
C. Cut back to 24 inches, allowing tree to develop with no additional pruning.
D. Cut back to 12 inches, allowing one bud to develop.
E. Cut back to 12 inches, with no further pruning.
F. Cut off top 3 inches of tree and notched above buds where limbs were desired before growth started.

Each treatment was used in 60 trees, 10 in each of six replications. The arrangement in the blocks was systematic. The data are presented in Table I.

It is to be noted that unless some pruning is done, the tree that fails to crown the first year forms a whorl of branches early in the second season. These are very close together, resulting in a weak structure. A considerable amount of the breakage observed in commercial orchards is due to this form of tree.

The trees in this experiment were in good soil, under good culture and well fertilized. Those cut back either to a 12-inch or a 24-inch height and trained to a single trunk produced crowns with good vertical distribution of the branches, but much too high. There is a wide difference of opinion among tung growers as to the most desirable height of crowning, but 190 centimeters is unquestionably far too high.

TABLE I—Effect of Different Pruning Practices on Number and Distribution of Branches

Treatment	Type of Tree	Number Lateral Branches Formed	Average Vertical Distance Between Branches (Cm)	Average Height to First Branch (Cm)
A........	Whorl	6.9	1.1	98
B........	Natural crown from 24 inch stump	8.6	4.0	193
C........	Vase form (bush) 24 inch trunk	7.7	6.3	9
D........	Natural crown from 12 inch stump	8.7	4.3	196
E........	Vase form (bush) 12 inch trunk	5.5	3.6	11
F........	Artificial head	3.8	12.6	47
Difference significant at .01 level............		1.0	1.2	...
Difference significant at .05 level............		0.7	0.9	...

Also eight to nine branches is too many for ultimate development of a strong tree. Whether cut back to a 12-inch or a 24-inch trunk, the number and vertical spacing of branches on the vase form tree is much improved over the controls. As previously mentioned, the branches form rather narrow angles with the trunk and whether they will prove stronger or weaker than the natural crown remains to be seen.

The trees developed by cutting back and notching of buds, have, by far, the most desirable vertical spacing between branches. The number of branches can be controlled, but in this case, is rather low, due to losses during cultivation, which had not been anticipated. The angles formed with the trunk are more acute than in the case of the natural crown but somewhat less acute than those of the vase form tree. Whether the crotches will prove significantly weaker than those of the natural crown, time only will tell. It is now believed that it will be good practice to notch and force out a number of extra buds since it has been observed that the more branches formed on the tree, the wider are their angles with the trunk. Excess branches can be removed after danger of breakage during cultivation is over.

Since all the trees used in this work are the progeny of a single parent tree, similar treatments were tried in another orchard of mixed seedlings with identical results.

The data of Rolf Buckley (1) indicate that height of crowning is an inherited characteristic. A second test was set up to obtain further data on this point and to determine whether the degree of cutting back at time of transplanting would significantly affect the height of crown. In the nursery at Lloyd, Florida, the progeny of open pollinated seed from individual trees ranged from 56 to 181 centimeters in mean crowning height. One hundred seedlings that crowned at a height of between 60 and 75 centimeters and 100 that crowned at between 90 and 105 centimeters in height were used for comparison; the former being arbitrarily designated as low crowns and the latter as high crowns. These were transplanted in a single orchard, the rows alternating between high and low crowning types. In each row, the trees were cut back alternately to 24 inches and 12 inches high. The soil and culture was such as to produce very vigorous growth. Measurements were taken about the middle of July, after all the trees had crowned. The data are presented in Table II.

It is clear that those trees that crowned high in the nursery, tended to produce high headed trees in the orchard, but within the limits of crowning height used in this test, it was possible by differential pruning to make the two groups crown alike. It must be clearly understood that varying the cutting height is a means of raising the height of head on low crowned types. It is not a means of obtaining satisfactory trees from types that crown excessively high.

In this very fertile field, all of the trees crowned higher than they had in the nursery during the previous season. By analysis of covariance, it was found that the regression of the gain in crowning height on height of cut is 0.944. After adjusting for height of cut, the mean gain for low crowned trees (45.3) is significantly greater than that of the high crowned group (39.4). It is believed that this must be due

TABLE II—MEANS OF CUTTING HEIGHT AND CROWNING HEIGHTS WITH ADJUSTED MEAN DIFFERENCE IN CROWNING HEIGHT AFTER TRANSPLANTING (CENTIMETERS)*

Treatment	Mean Height of Cutting (X)	Mean Height of Crown in Nursery	Mean Height of Crown in Orchard	Mean Difference in Crowning Height After Transplanting (Y)	Adjusted Mean Difference
High crown, high cut....	53.5	95.5	146.4	50.9	38.6
High crown, low cut.....	29.6	95.7	125.6	29.9	40.2
Low crown, high cut.....	51.7	69.6	123.5	53.9	43.3
Low crown, low cut.....	27.4	70.0	105.0	34.9	47.3

*byx = .944.

to local environment in the nursery. In selecting trees for the low crowned group, there would be a tendency to take those that had not only an inherent tendency to crown low, but also, ones in which the crown was low because of poor environment. The reverse would be true in selecting the high crowned group. When transplanted to the uniformly fertile field, the low crowned group would then tend to make greater gains than the high crowned ones.

A few crowned nursery trees were transplanted to the orchard without pruning and others were pruned by removing only excess laterals. Under conditions very favorable for growth, these trees did exceptionally well. The results justify more extensive trials another year.

As a result of these preliminary tests, it is believed that corrective pruning of tung trees shows considerable promise.

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Seasonal Changes in the Carotenoid Pigments in the Juice of Florida Oranges

By Erston V. Miller and J. R. Winston, *U. S. Department of Agriculture, Orlando, Fla.*

During investigations on the color in the rinds of citrus fruits it was noted that ether-soluble or plastid pigments are largely responsible for the color in the flesh as well as the peel of oranges. In the fall of 1938 studies were begun on the progressive changes in the pigments of the juice of Florida oranges during the maturing season. This paper presents data that are typical for early, mid-season and late varieties of oranges. A more detailed report will appear elsewhere.

Oranges were collected from 25 different plots. The experimental material consisted of 12 different varieties, some of them grown on two different root-stocks and some from two or three sections of the state. Collections were made once a month beginning in September.

Total carotenoids in the juice were determined by the following method. An aliquot of juice was filtered through a No. 5 Whatman filter in a Buchner funnel and the residue extracted with acetone. This extract was transferred to petroleum ether which was then washed with water and 1 per cent sodium carbonate and finally dried over anhydrous sodium sulfate. The petroleum ether extract was made up to a definite volume and the pigment content was determined colorimetrically,[1] the results being expressed as milligrams of total carotenoids per liter of juice. In this instance the term "total carotenoids" would include carotene, cryptoxanthin and xanthophyll (lutein), the first two of which are precursors of vitamin A. In order to compare the pigment content with other constituents the following analyses were also made at the time of sampling: total soluble solids, total acids, ascorbic acid and hydrogen ion concentration.

Table I shows the seasonal changes in carotenoid pigments, total soluble solids and total acids of Parson Brown (early), Pineapple (mid-season) and Valencia (late) oranges. It will be noted that the early and mid-season fruit showed a steady increase in juice pigments during the entire season. In the period from September to March total carotenoids in the juice of Parson Brown oranges increased from 2.21 to 5.89 milligrams per liter. Corresponding figures for the Pineapple oranges were 1.55 and 7.04. Valencia oranges showed a regular increase in juice pigments up to and including March, and a decrease in the next two months. That is, they contained 2.05 milligrams in October, 8.48 in March, but by April they had dropped to 7.70 milligrams per liter. The gradual increase in solids and the decrease in acids in all three varieties are also shown in Table I because it is these constituents that are customarily employed to express degree of maturity.

It will be seen fom Table I that pigmentation of the juice cannot be taken as an index of maturity. Parson Brown oranges, whose shipping

[1]Readings were made on a Clifford Photometer standardized with crystalline beta-carotene, using a blue filter which transmitted at approximately 458 mu. See *Jour. Agr. Res.* 60 (4): 261. 1940.

TABLE I—SEASONAL CHANGES IN TOTAL CAROTENOIDS AND OTHER CONSTITUENTS OF THE JUICE OF EARLY, MID-SEASON AND LATE FLORIDA ORANGES

Date Collected	Total Carotenoids (Mgs Per Liter)	Total Soluble Solids (Per Cent)	Total Acids (Per Cent)	Solids to Acid Ratio	Flavor
			Parson Brown on Sour Orange Stock		
Sep 18....	2.21	9.95	1.284	7.75	Slightly sour
Oct 23....	2.33	10.53	.818	12.87	Pleasantly tart
Nov 20....	4.04	11.30	.708	15.73	Pleasantly tart
Dec 18....	4.61	11.71	.672	17.43	Sweet
Jan 22....	4.88	12.17	.575	21.17	Sweet
Feb 19....	5.27	12.49	.455	27.46	Sweet
Mar 18....	5.89	13.00	.445	29.22	Sweet
			Pineapple Orange on Sour Orange Stock		
Sep 18....	1.55	8.11	1.338	6.06	Sour
Oct 23....	1.57	8.72	.936	9.32	Tart
Nov 20....	4.33	11.00	1.082	10.16	Tart
Dec 18....	5.05	11.30	1.014	11.14	Pleasantly tart
Jan 5....	5.51	11.90	.998	11.92	Pleasantly tart
Feb 19....	5.57	12.32	.810	15.21	Pleasantly tart to sweet
Mar 18....	7.04	12.90	.624	20.68	Sweet
			Valencia Orange on Sour Orange Stock		
Oct 30....	2.05	9.60	1.984	4.83	Very sour
Nov 27....	3.24	10.40	1.800	5.78	Sour
Dec 30....	4.78	11.49	1.586	7.24	Sour
Jan 29....	5.87	11.54	1.383	8.34	Sour
Feb 24....	6.42	11.72	1.514	7.74	Tart
Mar 26....	8.48	12.24	1.350	9.07	Tart
Apr 22....	7.70	12.16	.969	12.55	Pleasantly tart
May 20....	7.74	12.87	.858	15.00	Pleasantly tart

season is October and November, and Pineapple oranges, whose shipping season is November to February, are both marketed before they attain their maximum pigmentation in the juice. The Valencia orange, whose season is March to June, is marketed for the most part during its decline in juice pigmentation. Flavor tests made during the sampling period illustrate the same point. The Parson Brown was pleasantly tart (best flavor) in October and November and was considered sweet during the subsequent periods. The Pineapple orange was pleasantly tart on December 18 and pleasantly tart to sweet on January 22. The Valencia was pleasantly tart on April 22.

Mandarin oranges (*Citrus nobilis* Lour.) differ from those of the sweet orange type (*C. sinensis* Osheck) by having a deeper flesh color and consequently a greater quantity of carotenoid pigments in the juice. However the seasonal changes in the pigments in the juice are

TABLE II—MAXIMUM CAROTENOID CONTENT OBSERVED IN JUICE OF FLORIDA ORANGES

Variety	Total Carotenoids (Mgs Per Liter)
Hamlin	3.60
Ruby (Blood)	5.55
Pineapple	7.04
Valencia	8.48
Parson Brown	6.47
Temple	10.56
Dancy (Tangerine)	14.27
Owari (Satsuma)	20.23
King	24.52

similar for both types of oranges. The differences between these two types of oranges is shown in Table II which presents the maximum carotenoid content of the juice observed during the season. The sweet oranges showed a range in carotenoid pigments of 3.60 to 8.48 with an average of 6.22 milligrams per liter. Carotenoids in the juice of the Mandarins ranged from 10.56 to 24.52 with an average of 17.39.

The data presented here suggest that the vitamin A potency of the Florida orange not only varies with the variety but also increases during the maturing season.[2] The data also indicate that the Mandarin oranges are much higher in vitamin A potency than other types. This is significant because the bulk of the oranges shipped out of the state are the sweet orange type. It would seem desirable to make a greater use of the Mandarin type of oranges as a dietary supplement for both man and animals if not as a source of pure carotene or other precursors of vitamin A.

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[2]Although this statement is based on chemical determination of carotenoid pigments in all the varieties, it was substantiated by biological assays on two varieties conducted by Dr. Lela E. Booher of the Bureau of Home Economics. Parson Brown oranges sent to Dr. Booher were found to contain 42 international units of vitamin A per 100 milliliters juice in October and 80 in November. Similarly Pineapple oranges contained 75 units in the sample collected January 5 and 175 units on January 22.

Protection Against Loss of Moisture in Common Storage by Golden Delicious Apples[1]

By D. D. HEMPHILL and A. E. MURNEEK, *University of Missouri, Columbia, Mo.*

A CHARACTERISTIC of Golden Delicious apples and some other varieties is the tendency to lose considerable amounts of moisture under common storage conditions, which detracts from their appearance though the quality be satisfactory. The variety being excellent otherwise, it is highly desirable that in connection with home consumption some method of successfully lengthening its common storage period be developed. Golden Delicious apples, of course, keep well for many months in cold storage.

This experiment was undertaken to determine the effect of certain wax treatments on the loss of moisture by this variety under conditions of common storage. Waxing has been reported by Hitz and Haut (1) and by Smock (2) to decrease wilting of certain varieties of apples.

TESTS IN 1939

Representative lots of fruit were harvested at one week intervals, beginning September 18 and continuing until October 2. Lots 1 and 2, as designated in Fig. 1, were harvested on September 18, numbers 7, 8, 10, and 11 on September 25, and numbers 13 and 14 on October 2. A wax emulsion designated by the manufacturer as 489-AR was used at 20 per cent concentration. The fruit was weighed at the time of treatment and on November 11 and December 9, or approximately at monthly intervals. Wastage due to storage diseases was about the same for both waxed and unwaxed fruit.

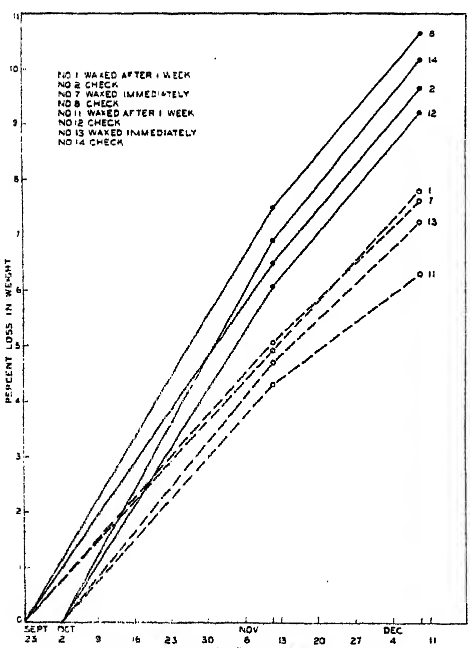

FIG. 1. Influence of waxing upon the loss of moisture by Golden Delicious apples in common storage, 1939.

Fig. 1 shows that in all cases waxed samples lost less moisture (7.22

[1]Contribution from the Department of Horticulture, Missouri Agricultural Experiment Station Journal Series No. 716.

per cent) than did unwaxed ones (9.92 per cent). Although the 2.70 per cent difference does not appear significant, the fruit varied notably in the degree of shriveling and firmness.

Tests in 1940

For this test the apples were harvested on October 4 and kept in common storage until the treatment on October 15. Three different waxes and two dilutions of each were used. The fruit was weighed at the time of treatment and on November 9 and December 13, or at about the same intervals as in 1939. The temperature of the storage room varied from 60 degrees F to 32 degrees F during the test period, the average being around 50 degrees F.

The results presented in Table I show that waxing decreases the loss of moisture. The average loss for the waxed fruit was 6.2 per cent and for unwaxed fruit 8.35 per cent, a difference of 2.15 per cent. Wrapping

TABLE I—The Effect of Wrapping and Certain Wax Emulsions on Loss of Moisture from Golden Delicious Apples in Common Storage (1940)*

Treatment	Percentage Loss of Moisture	
	November 9	December 13
Wax (489–AR 20 per cent) and wrapped	2.13	4.54
Wrapped only	4.16	7.45
Wax (489–AR 20 per cent)	3.81	6.09
No treatment	5.10	8.62
Wax (489–AR 14.28 per cent) and wrapped	3.61	6.41
Wrapped only	4.36	7.36
Wax (489–AR 14.28 per cent)	3.73	5.78
No treatment	5.04	8.72
Wax (S–112 33 per cent) and wrapped	2.76	6.36
Wrapped only	3.49	8.02
Wax (S–112 33 per cent)	4.01	6.64
No treatment	5.00	8.25
Wax (S–112 20 per cent) and wrapped	4.03	6.57
Wrapped only	4.67	8.10
Wax (S–112 20 per cent)	4.40	7.27
No treatment	4.92	8.65
Wax (489–A 33 per cent) and wrapped	3.70	6.00
Wrapped only	4.70	8.05
Wax (489–A 33 per cent)	2.77	5.15
No treatment	5.10	8.56
Wax (489–A 20 per cent) and wrapped	4.80	6.21
Wrapped only	5.65	7.97
Wax (489–A 20 per cent)	4.46	7.50
No treatment	5.60	9.42

*Experiment begun, October 15.

of waxed fruit decreased still further the moisture loss by .4 per cent, while wrapping of unwaxed fruit lowered it by 1.25 per cent. At the end of the test period, shriveling was very apparent of waxed but more so of unwaxed fruit. As in 1939, there was no significant difference in the amount of wastage due to storage diseases of treated and control apples.

Conclusions

From the results of these tests, it is apparent that waxing decreased appreciably, and wrapping to a slight extent, the loss of moisture of Golden Delicious apples in common storage. Waxed as well as un-

waxed fruit, however, were no longer marketable as No. 1 apples after approximately two months in common storage. Waxing may have a practical value if a relatively high humidity is maintained in the storage room, and if the common storage period is comparatively short.

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Fruit Juice Concentration by Freezing and Centrifuging[1] [2]

By LOWELL R. TUCKER, *Massachusetts Agricultural Experiment Station, Amherst, Mass.*

THE advantages of concentrating fruit juice to reduce container, storage and transportation costs are generally appreciated. The maintenance of high quality in the concentrated product by freezing the juice and separating the ice from the concentrated liquid has been attested by Irish (4), Mottern (5), Brown and Foulk (1) and others. The general public is not familiar with concentrated fruit juices nor acquainted with juices concentrated by the freezing process. Acquaintance may come only if small activities start, prove to be practical and develop into industries. The numerous installations of cold storage lockers has made freezing facilities widely available and should furnish opportunities for small scale concentrating plants.

The various procedures for accomplishing the concentration by freezing are based on two fundamentals, namely, (a) when fruit juice is partially frozen, only the water crystallizes leaving a solution containing the soluble solids, and (b) the solution may then be separated from the ice by some method such as the application of centrifugal force. Gore (3) recommended such a procedure for concentrating cider. Caldwell (2) partially concentrated pectin solution by a similar procedure. Irish (4) confirmed the findings of Gore (3) and also recommended the high quality of some other concentrated juices. Tressler, Joslyn and Marsh (6) have given a detailed summary of information regarding the concentration of fruit juices.

A method for concentrating juices by freezing and centrifuging that may be used at cold storage locker plants has been developed by the writer. The method was tried on several fruit juices to determine the limitations of the process and its effect on different juices.

A summary of the concentrating method follows. Aluminum pudding pans were used as containers to hold the juice during the freezing process. A pan was set level, filled, covered by inverting a pan of larger diameter over it, then the entire ensemble was inverted by a rapid upward swinging movement. The inverted ensemble was set on a level, compressed cork board or other insulating material in a cold room where freezing from the top and sides occurred. When about half of the material was frozen, the bottom pan was removed from the pudding pan and contents. The pan and contents were then whirled on a centrifugal plate until the liquid was removed from the porous block of ice. If further concentration was to be effected, the procedure was repeated with the liquid obtained.

FREEZING STUDIES

Considerable attention was given to the effect of the shape of the container on the formation of ice. The inverted pudding pan was finally

[1]Condensed summary of thesis submitted in partial fulfillment for the degree of Doctor of Philosophy, Massachusetts State College, Amherst, Mass., June 1940.
[2]Contribution No. 400, Massachusetts Agricultural Experiment Station.

selected because when placed on an insulated support, its shape caused the freezing to occur from the top and sides in such a way that most of the concentrate was in the lower central portion of the mass. It was more efficient than a parallel sided container in placing the concentrate where it could be removed by centrifugal treatment. The ice crystal aggregates forming from the sides of the containers usually were vertical radial sheets. The sloping sides of the pudding pan caused the aggregates to point downward as well as inward and thereby reduced the crowding which perpendicular sides caused. The final result was that very few secondary ice crystal aggregate systems were formed and the concentrate between the ice was not seriously trapped (Fig. 1).

It is known that the amount and rate of freezing affect ice crystal formation. At low temperatures more water will eventually freeze than at higher temperatures, also the first ice will be formed more rapidly. Freezing at a slow rate causes larger crystals to form and more space between the crystals than at a rapid rate. In this work relatively slow freezing has been most advantageous. Pudding pans of 1 gallon size gave more efficient results than those of 2 quart size; larger pans undoubtedly would have been still better. With pans of any given shape, an increase in size increases the volume more rapidly than the

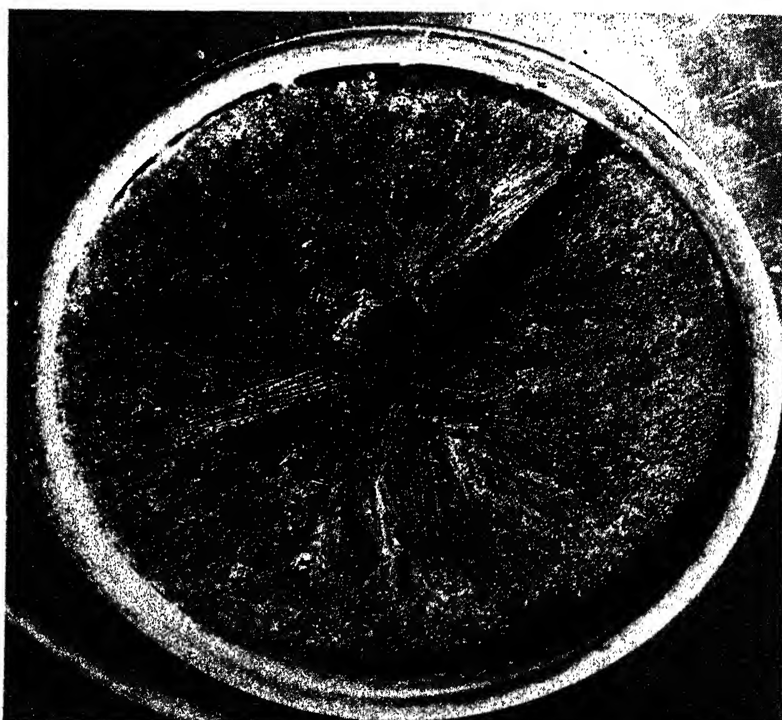

FIG. 1. Ice left in pan after removal of the concentrated juice by centrifugal force. Note size, shape, location and arrangement of ice crystal aggregates.

surface, reduces the rate of freezing, and facilitates separation of ice and concentrate.

Separation Studies

Since freezing alone does not efficiently separate the ice and concentrate, and a press does not give satisfactory results, centrifugal force was used. Centrifugal force may be expressed in terms of gravities and the amount calculated by the following formula. Force = $.000341NR^2$ when N = radius in feet and R = revolutions per minute. One gallon pudding pans of frozen juice placed on a centrifugal plate and whirled at the rate of 1,400 revolutions per minute usually received sufficient force to make the separation.

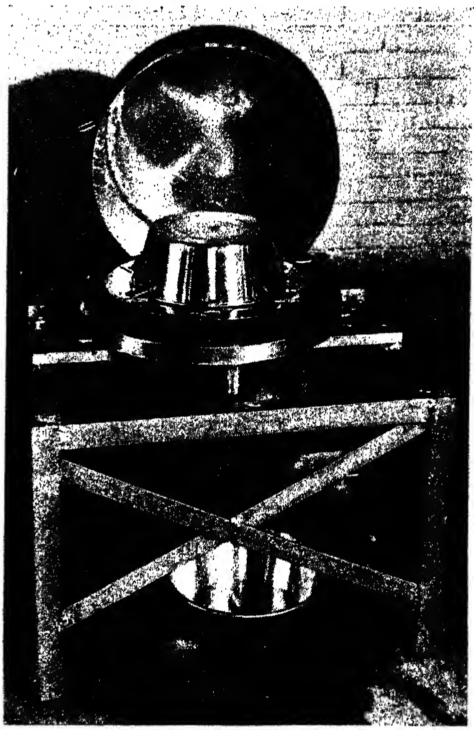

Fig. 2. The centrifuge with pan attached in whirling position. The large container at the back is the hood for the centrifuge. Another view of a pan used for freezing and whirling may be seen on the floor under the drain.

Fig. 2 shows the machine used. It was built under the direction and with the help of Professor C. I. Gunness of the Agricultural Engineering Department of Massachusetts State College. This machine was also used to drain juice rapidly and efficiently from cooked fruit not adapted to pressing.

Juice Tests

The methods of testing the juices, both before and after concentrating, were as follows. Samples in 8-ounce jars were processed by immersion in a 180 degrees F waterbath for 20 minutes, then later tested at one time, and the results compared with respect to (a) soluble solids, (b) acid content, and (c) viscosity (Table I). Brix hydrometer readings of the concentrate and melted ice lots at the time of separations were used to calculate losses of soluble solids.

Soluble solids content of the stored samples was determined by refractometer readings corrected for temperature. Acidity of the juices was determined, both as the pH and the ml of 0.1 N NaOH necessary to neutralize the acid present in 3 ml of sample diluted with 50 ml of

TABLE I—COMPARATIVE TESTS OF THE DIFFERENT FRUIT JUICES BEFORE AND AFTER CONCENTRATING

Kind and Variety	Concentration	Viscosity		Soluble Solids	Acidity	
	Before—B After—A	Temp Degrees F	Seconds*	Per Cent	pH	Ml. 0.1 N NaOH
Water	—	69	32.7	—	—	—
Water	—	67	32.6	—	—	—
Cooked apple—Crimson Beauty	B	71	81	8.6	3.07	13.8
Cooked apple—Crimson Beauty	A	71	384	14.6	3.09	24.9
Apple pomace—mixed	A	71	260	9.9	3.60	5.7
Blueberry—Rubel	B	71	51	7.6	3.15	10.2
Blueberry—Rubel	A	71	379	18.6	3.12	21.5
Blueberry (pectinol treated)—Rubel	A	70	51	45.2	3.00	56.4
Cherry—Montmorency	B	72	36	11.7	3.40	20.5
Cherry—Montmorency	A	72	172	37.5	3.21	74.0
Cherry—English Morello	B	71	38	15.4	3.22	33.0
Cherry—English Morello	A	71	108	39.5	3.15	93.5
Cooked cranberry (pulp and water)	B	70	52	3.6	2.50	19.4
Cranberry—Early Black	B	71	35	7.8	2.40	45.9
Cranberry—Early Black	A	71	79	32.2	2.20	230.9
Currant—Wilder	B	71	49	10.4	3.10	36.5
Currant—Wilder	A	71	658	24.3	3.10	84.6
Elderberry—mixed	B	71	36	9.3	4.30	9.9
Elderberry—mixed	A	71	90	37.7	4.13	36.9
Grape—Concord	B	71	36	11.1	3.27	15.1
Grape—Concord	A	71	77	41.0	3.00	42.7
Grape jelly stock—mixed (mostly Concord)	B	71	39	9.7	3.20	13.3
Grape jelly stock—mixed (mostly Concord)	A	71	288	33.7	2.88	38.1
Peach—Radiant	B	71	61	9.4	3.30	10.0
Peach—Radiant	A	71	†	32.0	3.39	31.0
Plum—Albion	B	71	132	11.6	3.14	12.2
Plum—Albion	A	71	†	25.5	3.10	30.4
Plum—Burbank	B	71	83	8.7	3.00	16.2
Plum—Burbank	A	72	†	19.3	2.80	33.4
Red Raspberry—Newburg	B	71	40	8.7	2.93	28.7
Red Raspberry—Newburg	A	71	186	22.1	3.02	74.9
Strawberry—Howard 17	B	69	40	7.6	3.42	12.1
Strawberry—Howard 17	A	68	136	21.9	3.38	39.4

*Seconds required to empty bowl of 50 ml. pipette at room temperature.
†Too viscous for pipette.

distilled water. The pH readings were taken with a Beckman glass electrode machine. The total acidity determinations on strawberry juices were made by using phenolphthalein as indicator. However, most fruit juices contained pigment which either masked the indicator color from the start or, with the addition of NaOH, changed color before the phenolphthalein. A different procedure was required and the use of the quinhydrone electrode to titrate to a pH of 7 was the handiest equipment available. This method was slow but gave consistent results.

Viscosity was measured by noting the time in seconds required for 46.6 ml of juice at 68 to 71 degrees F to flow from a 50 ml pipette. The last 3.4 ml space was not used because the rate of flow from this portion of the pipette did not resemble that from the bulb. A duplicate reading usually gave less than one per cent variation from the first.

EFFECTS OF CONCENTRATING

The nature of materials dissolved sometimes was found to be much more important than the total quantity. The importance of this factor was greater in some juices than was expected. Concentration of grape

TABLE II—RUBEL BLUEBERRY JUICE CONCENTRATION DATA

Concentration	Soluble Solids of Concentrate		Soluble Solids of Ice		Soluble Solids Loss
	Per Cent*	Pounds	Per Cent*	Pounds	Per Cent*
Before	9.2	2.30	—	—	—
First	18.5	1.85	3.3	0.48	20.6
Second	21.2	1.01	11.9	0.57	36.1
Total	—	—	—	—	49.3

*Hydrometer readings.

juice by this method caused the formation of a dark colored precipitate, probably argol, and prevented its further formation when the juice was stored. Intensive concentration of rhubarb juice caused formation of a large amount of precipitate. In juices from cooked fruits the dissolved pectinous substances and sometimes starchy materials increased the viscosity and became very troublesome. This rate of increase in viscosity was much more than the rate of increase in percentage of soluble solids, (Table I) and usually limited the degree of concentration that could be accomplished. Elderberry and strawberry were the only cooked juices tested that did not seriously show such limitations. When pectinous juices were concentrated sufficiently a jell would form that could not be readily centrifuged from the ice. Cooked currant, apple, peach and blueberry were in this class.

The use of a pectin destroying enzyme on such viscous juices as blueberry lowered the viscosity to or beyond that of the uncooked juice so that concentration to about 45 per cent soluble solids could be efficiently accomplished (Tables II and III).

The concentration of soluble solids in a juice affected the concentrating results. With high concentrations the amount of ice formed in proportion to the quantity of soluble solids present was low and the ice sheets were small. The combined result was that each successive concentrating process tended to increase the loss of soluble solids for any given amount of concentration. With juices from uncooked fruits, which usually have low viscosities, high concentration often was the factor limiting the amount of water removal that could be efficiently accomplished.

The juices from cooked fruit usually could be concentrated to two-thirds or one-half volume, and the uncooked or pectinol treated juices usually could be concentrated to one-third to one-fifth their original volume or around 45 per cent soluble solids. Therefore, this method

TABLE III—PECTINOL TREATED RUBEL BLUEBERRY JUICE CONCENTRATION DATA

Concentration	Soluble Solids of Concentrate		Soluble Solids of Ice		Soluble Solids Loss
	Per Cent*	Pounds	Per Cent*	Pounds	Per Cent*
Before	9.2	1.53	—	—	—
First	28.6	1.57	0.0	0.00	0.0
Second	46.0	1.38	5.0	0.10	6.8
Total	—	—	—	—	6.8

*Hydrometer readings.

of concentration is better adapted to uncooked and pectinol treated juices than to cooked juices.

Comparisons of Fruit Juices

The juices of apple, blueberry, cherry, cranberry, currant, elderberry, grape, peach, plum, red raspberry and strawberry fruits were concentrated (Table I). Also, unconcentrated juices of several varieties of different kinds of fruits were tested and compared. The results of the variety tests showed two important facts; (a) that there is a wide range in the characteristics between varieties of each kind of fruit so that statements with regard to any one kind of fruit must be general, and (b) that requirements for fruits that are to be used for juices do not parallel standards set for fruits to be used as raw dessert. Dessert fruit varieties often have low acidity, variable and often unsatisfactory pectin and starch content, flesh color and skin pigments. Color, for example, in the cooked juices of some blueberry varieties is a very dark, inky, blue black; while in others a red color also exists, which increases attractiveness. Also, a red tinge is found in some, but not all, selections of elderberries. The juice color of strawberries is equally as variable having, besides the expected many shades of red, also brown, and occasionally a bluish tinge. A bluish tinge may also be found in the cooked juices of some varieties of red currants and red raspberries.

Summary

A study of the development and pattern of ice crystal formation in sugar solutions and fruit juices made possible the development of a method for concentrating fruit juices by freezing and centrifuging that seemed practical on a small scale. The method is described.

Highbush blueberry, cherry, currant, elderberry, peach, plum, red raspberry, strawberry, apple, cherry and grape juices obtained by heat extractions were concentrated and tested. The concentration did not injure quality of any of these juices. The amount of concentration that could be obtained without serious loss of soluble solids was usually limited by the viscosity of the juices. This was especially true with cooked juices.

Treatment of the viscous juices, as blueberry, with a pectin destroying enzyme reduced the viscosity enough to remove this factor of limitation to the concentrating process and permitted concentration to 45 per cent soluble solids, about one-fifth volume. The process seems to possess commercial possibilities.

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Carbon Dioxide Treatment of Strawberries and Cherries in Transit and Storage

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VARIOUS workers (1, 2, 3, 4, and 5) have demonstrated the usefulness of the technique of carbon dioxide treatment of certain small and stone fruits. This study was undertaken to determine the feasibility of this procedure with certain New York varieties and to study the atmospheric and temperature combinations best adapted to these varieties. The usefulness of this technique was studied for short periods during transit in a gas tight refrigerated truck and during longer periods in storage.

Methods

Studies were made during transit in a gas tight, metal chamber known as a "Lindsay" truck body. The metal sheets had been fastened down on the tensioners with a layer of gun-grade caulking compound to insure gas-tight joints. Tests for leakage on this structure showed only extremely small losses of carbon dioxide. This structure also was insulated and refrigerated. A blower type cooler in the structure was capable of removing field heat at a rate sufficient to lower the fruit temperature of 600 pounds of strawberries from 70 degrees F to 45 degrees F in 4 hours. The capacity of the chamber was approximately twelve 24-quart crates. Through a large door at one end of the chamber easy access could be had into the unit. The door was made gas tight by use of a rubber gasket seal which was covered with vaseline. By means of temperature indicators, thermostats, and a portable Orsat gas analysis apparatus the temperature and atmospheric conditions inside the chamber could be observed and controlled. A tube into the chamber for the introduction of carbon dioxide and a tube for the release of excess pressures and for sampling the atmosphere were provided. Liquid carbon dioxide in cylinders was taken along on the trips and carbon dioxide was released into the chamber as required.

For the longer periods of storage small gas tight chambers of 2-bushel capacity were used. Carbon dioxide was supplied as needed and daily checks were made on the concentration in the chambers. The concentration of CO_2 was not allowed to fluctuate from the desired value more than 2 to 3 per cent from day to day. Where a low oxygen atmosphere was used the normal air was flushed out of the chamber by use of nitrogen. This was then supplanted by the proper mixture of carbon dioxide, oxygen, and nitrogen to give the desired concentrations of these constituents.

Results

Experiment 1:—In order to gain information on the transportation and storage of New York small fruits in advance of the local season, the refrigerated truck was taken to Salisbury, Maryland, where 13 cases of Chesapeake strawberries were secured. The berries were at

TABLE I—RESPONSE OF CHESAPEAKE STRAWBERRIES TO CARBON DIOXIDE TREATMENTS AFTER TRANSIT IN CARBON DIOXIDE*

Treatment	Days Held in Storage													
	1		2		3		4		5		6		7	
	Condition	†	Condition	†	Condition	†	Condition	†	Condition	†	Condition	†	Condition	†
Air check	Poor, dark red, soft, some scald	1	Very poor, all scalded, mushy, moldy	0	Discarded, unmarketable	..	———	.	———	..	———	..	———	..
70 degrees F, 30 per cent CO_2 from dry ice	Fair, slight scald	2	Fair, dull	2	Very poor dull, slight off flavor	1	Discarded, unmarketable	..	———	—	———	..	———	..
70 degrees F, 30 per cent CO_2	Fair, firm, bright	1	Poor, dull, soft, poor flavor	1	Very poor, mold, flat flavor	1	Discarded, unmarketable	.	———	—	———	—	———	..
50 degrees F, air	Fair, soft	2	Poor, soft flat taste, dull color	1	Very poor, poor quality, dull	1	Discarded, unmarketable	.	———	...	———	..	———	—
50 degrees F, 15 per cent CO_2	Excellent, bright, firm	2	Excellent, bright, firm, good flavor	2	Good, bright firm, good flavor	2	Good, bright firm, good flavor	2	Good, bright, firm	2	Good, bright, good flavor	1	Fair, firm, bright, good quality	0
50 degrees F, 20 per cent CO_2	Excellent, firm, bright	2	Excellent, firm, bright	2	Good, bright, firm	2	Good, bright firm, fair flavor	2	Good, bright, firm	2	Good, firm, bright, fair quality	1	Bright, fair, fair quality	1
50 degrees F, 25 per cent Co_2	Excellent, bright, firm	3	Excellent, bright, firm	3	Good, bright firm, good flavor	2	Bright, good, firm	2	Good, bright, firm, fair quality	2	Good, bright, firm, slight "off" flavor	2	Good, firm, bright, poor quality	2
50 degrees F, 30 per cent CO_2	Excellent, bright, firm	2	Excellent, bright, firm	1	Good, bright firm, "off" flavor	1	Good, firm bright, flat flavor	1	Discarded, unmarketable	0	———	—	———	—
50 degrees F,‡ 30 per cent 20–10	Excellent, bright, firm	3	Good, firm, good quality, bright	3	Good, bright firm, good quality	2	Good, firm, bright color, fair quality	2	Good, bright, fair quality	2	Fair, bright, firm, slight mold	1	Fair, bright, poor quality	0
55 degrees F, 30 per cent CO_2	Excellent, bright, firm	2	Excellent, bright, firm	2	Good, bright firm, slight "off flavor"	2	Good, bright, "off" flat flavor, firm	2	Good, bright, firm	2	Good, bright, firm, off flavor	2	Good, bright, bad flavor	1

*During 10 hour trip strawberries held in 25 per cent carbon dioxide at 55 degrees F; air check was held continuously in outside air although kept in shade.
†Additional days marketable. Fruit held after removal at 70 degrees F and examined daily for marketability.
‡This treatment was treated with 30 per cent carbon dioxide the first day in storage, 20 the second, 10 the third, and none the fourth. This treatment was to simulate a commercial room with a high rate of leakage.

commercial picking maturity. Twelve of the crates were placed in the chamber, cooled, and treated immediately with 25 per cent carbon dioxide. One crate was left outside the chamber but in the shade as an air check. The return trip to Ithaca was made at night and the outside temperature varied from 50 to 60 degrees F. A comparable temperature (55 degrees) was maintained inside the chamber during the trip.

On arrival at Ithaca at 7:00 the following morning, the fruit was removed from the chamber, the boxes divided into 10 lots that were subjected to the treatments shown in Table I. Inspection of the air check fruit at the time of arrival in Ithaca showed that it had ripened up markedly and had taken on a dull red color in addition to some softening. It also appeared somewhat shrunken and had settled in the boxes.

The condition of the berries transported with carbon dioxide inside the chamber was excellent on arrival, the berries being bright in appearance, plump, and showing no loss of water. As the berries showed little or no softening there was no apparent settling and the boxes remained well filled. There was an average of 33 per cent firm white tips and in general the condition was still very similar to that at the time of picking. Three quarts were taken daily from each treatment for detailed examination. After examination, these three boxes of fruit were placed in a room at about 70 degrees F and with low relative humidity. The length of marketability after storage was determined both from the percentages of unsaleable fruits as well as from the observed condition and quality of the fruit at daily examinations. Sweating of the fruit was eliminated by using storage temperatures sufficiently high to avoid condensation of moisture on the fruit after removal from storage. From these studies of the behavior of the Chesapeake strawberry, it is apparent that a concentration of 15 per

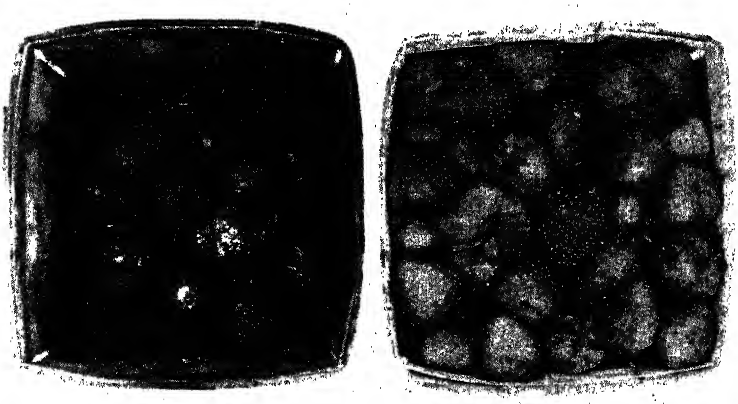

FIG. 1. Chesapeake strawberries: Left, held continuously at outdoor temperatures in shade for 5 days. Right, held in transit for 10 hours at 25 per cent carbon dioxide at 55 degrees F and then 4 more days with 15 per cent carbon dioxide at 50 degrees F.

cent carbon dioxide at 50 degrees F was the most desirable storage treatment for this variety. As the concentrations of carbon dioxide were increased up to 20 and 25 per cent, the quality declined after several days, although the berries remained firm, bright, and in good condition. The treatment in which the concentration of CO_2 was permitted to decline from 30 to 0 per cent over a period of 4 days also resulted in poor quality.

Experiment 2:—In this experiment carried on in the Hudson River Valley, the same portable gas tight chamber was used with the strawberry varieties Catskill, and Connecticut No. 123 and No. 143. This fruit was harvested at commercial picking maturity and placed directly in the chamber where a concentration of 17 per cent carbon dioxide was maintained at a temperature of 50 degrees F for 3 days. Checks of these varieties were stored at the same temperature but no CO_2 was added to the confined air. At the end of the gas treatment the fruit was removed for inspection. After inspection it was held for 8 hours in a warm room at 80 degrees F at low humidity to simulate actual store or marketing conditions, and then placed in a small domestic refrigerator at 40 degrees F. All check lots showed a dull red color and a markedly ripened condition when removed from storage. The carbon dioxide treated fruit, however, 60 hours after removal from the initial carbon dioxide treatments, were still bright, firm, of good quality and in good marketable condition. Check lots of each variety at this time showed a scalded condition of the fruit, a slightly sunken condition in the boxes, and some mold had begun to develop.

Experiment 3:—Catskill strawberries grown in Oswego County, New York, were next subjected to CO_2 treatments in the gas tight truck. Three crates of 24 quarts each were placed in each of the following treatments: No. 1, in an atmosphere of 17 per cent carbon dioxide at 50 degrees F; No. 2, in air at 50 degrees F; and No. 3, in air at 32 degrees F. Treatments were for a period of 84 hours. The berries treated with carbon dioxide were excellent in general appearance, of a high red color, firm and of good quality on removal from treatment. Berries kept at 32 degrees in air without additional CO_2 were darker red in color and in a riper condition than those from the carbon dioxide treatment; the quality was good although rather severe sweating occurred on the cold fruits when they were removed from the treatment. The lot kept at 50 degrees in air without additional CO_2 was much darker red in color. Although the boxes remained full, there was a slight mold growth and the fruit had begun to taste slightly flat in flavor.

Two cases of berries from each treatment were placed on sale at each of the two fruit markets in Ithaca. Consumer preference enabled the store clerks to sell the carbon dioxide treated fruits for 15¢ per box, and at each store these fruits were sold rapidly. The fruit kept at 32 degrees in air maintained a good marketable appearance. However, by the end of the second day the flavor was somewhat flat and all berries from this treatment and from 50 degrees in air were discounted in price. At various times throughout the two-day marketing period entire boxes of berries from the treatment at 50 degrees in air

TABLE II—RESPONSE OF SCHMIDT SWEET CHERRIES TO VARIOUS TEMPERATURES AND CO_2 TREATMENTS

Treatment	Removed for Inspection After 2 Weeks Storage			Removed for Inspection After 3 Weeks Storage			Removed for Inspection After 4 Weeks Storage		
	Condition	Days Marketable at 70 Degrees F	Cause of Discard	Condition	Days Marketable at 70 Degrees F	Cause of Discard	Condition	Days Marketable at 70 Degrees F	Cause of Discard
32 degrees F air	Good, firm, stems shriveled	1	Soft, brown stems, severe pitting	Fair, stems withered, some pitting	1	Soft, over ripe, severe pitting	Discarded, unmarketable	–	———
40 degrees F air	Good, ripe, slight shrivel, green stems	1	Over ripe, brown stems, some pitting	Discarded, unmarketable	–	———	———	–	———
50 degrees air	Poor, stems dried, over ripe	–	Discarded, unmarketable	———	–	———	———	–	———
70 degrees F air	Very poor, brown stems, over ripe	–	Discarded, unmarketable	———	–	———	———	–	———
40 degrees F and 10 per cent Co_2	Good, slightly better than 40degrees F air, green stems	2	Over ripe, brown stems, slight pitting	Fair, stems fairly green and plump, good quality	2	Soft, over ripe	Fair, flavor fair	2	Dried stems, poor flavor, soft
40 degrees F 20 per cent CO_2	Good, next best after 5–2, green stems, slightly shriveled	4	Over ripe, brown stems, slight pitting	Good, stems green, slight pitting, good quality	3	Soft, over ripe	Good, flavor good	2	Dried stems, poor flavor, soft
40 degrees F 5 per cent CO_2 2 per cent O_2	Excellent, most stems green and plump good flavor	4	Over ripe, brown stems, slight pitting	Excellent, quality good, slight pitting	3	Over ripe	Good, flavor flat	2	Dried stems, poor flavor, soft
50 degrees F 15 per cent CO_2	Fair to poor, ripe, stems slightly shriveled	1	Soft, over ripe, brown stems, some pitting	Discarded, unmarketable	–	———	———	–	———
50 degrees F 25 per cent CO_2	Fair, stems slightly browned, flavor good, ripe	2	Brown stems, soft, slight pitting	Discarded, unmarketable	–	———	———	–	———

were removed and discarded in order to maintain saleable appearance of the fruit. All fruits in this lot were dark red, over-ripe, scalded and of poor appearance and 11 quarts in all were discarded.

Experiment 4:—Schmidt, Napoleon, and Windsor sweet cherries grown at Trumansburg, New York were tested in an effort to prolong their normal storage life. Various combinations of carbon dioxide concentrations and temperature were employed as indicated in Table II. In one treatment an atmosphere of 5 per cent carbon dioxide and 2 per cent oxygen was employed to determine the merit of a very low oxygen atmosphere.

Results obtained with the Schmidt variety are presented in Table II. Results obtained with the other two varieties, in general are similar to those obtained with the Schmidt, and are not included in this table. Table II indicates that the best treatment with Schmidt was 20 per cent carbon dioxide at a temperature of 40 degrees F. Upon removal from treatment of 4 weeks, the cherries were still marketable at room

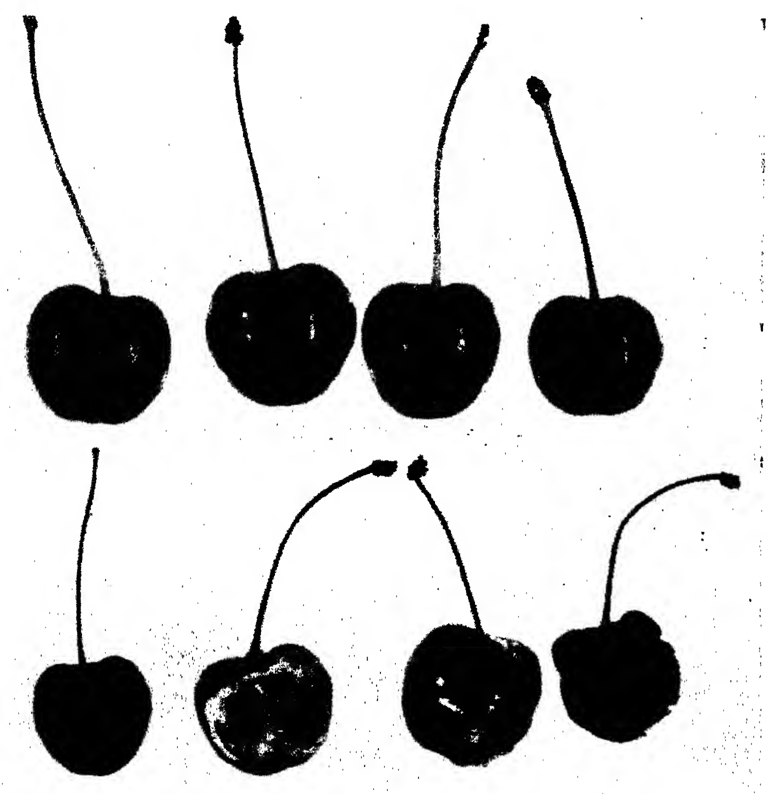

FIG. 2. Windsor sweet cherries after 3 weeks storage and then held 2 days at 70 degrees F. Top, 20 per cent carbon dioxide at 40 degrees F. Bottom, 70 degrees F air continuously.

temperature for 2 days, but by this time the flavor had declined somewhat and it is thought that 3 weeks would be about the limit for best storage. A slight amount of surface pitting occurred in the Schmidt variety under all treatments, but this defect did not appear in the other varieties tested. The use of a low oxygen atmosphere resulted in no better keeping than with 20 per cent carbon dioxide at the same temperature. This low oxygen atmosphere (5 per cent CO_2–2 per cent O_2) was tested because it could possibly be maintained commercially without the addition of carbon dioxide to the chamber, as is the case in controlled atmosphere storage with apples.

Windsor seemed to respond best to an atmosphere containing 20 per cent carbon dioxide at a temperature of 40 degrees F. While it was kept four weeks in this treatment in fair condition, it probably was not in best marketable condition after 3 weeks. The low oxygen atmosphere was comparable to the foregoing treatment in its effect on the fruit. Fruit stems remained plump and green for this period of time.

Napoleon sweet cherries did not respond quite as well as the other two varieties. After 4 weeks' storage they were definitely unmarketable because of poor quality and a discoloration of the flesh. This flesh discoloration appeared on all 40 degrees F CO_2 treatments, so it is possible that it was an injury due to carbon dioxide. This variety kept for 3 weeks with just fair quality and condition in 20 per cent carbon dioxide at 40 degrees F. There was somewhat less discoloration and slightly better keeping in the low oxygen atmosphere but not enough so to justify this treatment commercially. The stems remained in plump green condition throughout the test.

Summary

Four varieties of strawberries were examined as to their response to various carbon dioxide and temperature combinations. These varieties kept in good marketable condition for 3 to 4 days in a continuous treatment of 15 per cent carbon dioxide at 50 degrees F. They remained marketable at room temperature after the storage treatment for a period of time sufficiently long to have them marketed and consumed in good condition. This treatment was superior to ordinary cold storage at 32 degrees F because of better color of berries, less sweating and subsequent mold, and slower ripening.

Three varieties of sweet cherries were tested as to their adaptation to carbon dioxide treatments. In this study a concentration of 20 per cent CO_2 at 40 degrees gave the best results. Under this treatment the response of Windsor was better than that of Schmidt or Napoleon. Three weeks seemed to be the maximum time that these varieties could be kept in storage in prime condition under this treatment although Windsor was kept in fair condition for 4 weeks.

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Carbon Dioxide-Oxygen and Storage Relationships in Cranberries[1] [2]

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FRANKLIN (3) first advocated the ventilation of cranberries and low temperature storage in 1915. As early as 1920, Morse and Jones (6) showed that respiration in stored cranberries was much higher with a rise in temperature. Shear, Stevens, and Rudolph (7) reported that cranberries stored in tightly closed containers spoiled rapidly while those stored in the presence of air kept much better. The spoilage was thought to be due to the accumulation of CO_2 from the respiring fruit. The spoilage fungi were also somewhat inhibited by the presence of CO_2. Esselen and Fellers (2) demonstrated that the CO_2 and CO_2/O_2 ratio are closely associated with keeping quality of cranberries. For example, Howes cranberries stored at 3 degrees C (37.4 degrees F) for 24 days contained 7.98 per cent CO_2 and 12.42 per cent O_2 (CO_2/O_2 ratio 0.64). When stored at 24 degrees C (75.2 degrees F) for 21 days, the CO_2 content was 17.62 per cent and the O_2 content 5.39 per cent (CO_2/O_2 ratio 3.27).

Wright, Demaree, and Wilcox (8) found that 2.22 degrees C (36 degrees F) was the most suitable temperature for storage of New Jersey cranberries over a 4-month period. Temperatures below 2.22 degrees C (36 degrees F) caused low temperature breakdown. Aside from a general increase in acidity and decrease in pH value in storage, other chemical or physical changes were not significant. Clague and Fellers (1) found that the varieties with the best keeping qualities did not always have a high benzoic acid content, so that apparently factors other than benzoic acid content alone must be largely responsible for the keeping properties of cranberries. Pectin and soluble solids content did not correlate with keeping quality. Most good keeping varieties had a high acid content.

Experimental

Internal Atmosphere in Stored Cranberries

A three year investigation has been completed on the changes in the internal atmosphere of the cranberry during storage. Determinations of the CO_2/O_2 ratio were made using the method devised by Esselen and Fellers (2). Early Black and Howes varieties of cranberries were used in all the experiments. They were picked when partly colored (somewhat immature) and when fully colored (commercially mature) and held under various storage conditions.

[1]Contribution No. 392, Massachusetts Agricultural Experiment Station.

[2]Dr. Henry J. Franklin, Head of the Massachusetts Cranberry Experiment Station at East Wareham, Massachusetts actively cooperated in this investigation.

Results

Representative data are presented in Tables I and II. While extensive additional data were obtained, their inclusion in this paper would serve no useful purpose since they are largely inconclusive.

The data indicate that as the length of storage at room temperature 21.1 degrees C (70 degrees F) increases, there is generally a corresponding increase in the CO_2 content thereby causing an increase in the CO_2/O_2 ratio. However, when the cranberries were held at 2.2 degrees C (36 degrees F) for several weeks, the CO_2/O_2 ratio changed but little despite a slight increase in the percentage of unsound berries.

All lots of cranberries stored at common storage, *i. e.* at higher temperatures, (see Table II) had higher ratios and a greater incidence of spoilage than those lots held at cold storages for an equal length of time.

TABLE I—Effect of Storage on the Gas Content of Early Black Cranberries

Storage Conditions			Gas Content		
Time (Days)	Temperature (Degrees C)	Decayed Berries (Vol Per Cent)	CO_2 (Per Cent)	O_2 (Per Cent)	Ratio CO_2/O_2
0	—	6	10.4	14.8	0.7
7	21.1*	10	14.5	9.2	1.6
14	21.1	35	17.5	7.1	2.5
21	21.1	90	19.8	6.1	3.3
28	21.1	100	19.0	5.5	3.5
7	2.2*	7	7.4	14.8	0.5
14	2.2	7	6.3	18.0	0.3
21	2.2	10	5.7	17.1	0.3
28	2.2	13	3.9	16.5	0.2

*21.1 degrees C (70 degrees F); 2.2 degrees C (36 degrees F).

Sound cranberries commonly give CO_2/O_2 ratios of from 0.3 to 1.0. Such fruit normally possesses good keeping quality. When held at –1.1 degrees C (30 degrees F) for 4 months, the cranberries seldom had a CO_2/O_2 ratio over 1.0. At the higher storage temperatures, the ratios were usually between 1.0 and 3.0. In general, the berries picked while somewhat immature had a lower ratio than riper berries after prolonged storage. However, the maturity at picking did not seem to affect the rate of spoilage in storage as the immature berries decayed to the same extent as the riper ones. There was little difference in the content of CO_2 and O_2 in freshly picked immature and fully mature cranberries.

Discussion

Although in any one storage experiment with a given set of conditions, the ratio will increase and the percentage of decayed berries will increase, there is little evidence to show that one will increase proportionately with the other. However, certain generalizations can be made. Sound cranberries commonly give CO_2/O_2 ratios of 0.3 to 1.0. Normally, such fruit possesses good keeping quality. Cranberries whose CO_2/O_2 ratios are higher than 1.0 seldom keep well in storage.

TABLE II—CO_2/O_2 RATIOS AND SPOILAGE IN CRANBERRIES IN COMMERCIAL STORAGE HOUSES

Kind of Storage and Temperature (Degrees F)	Howes—Partly Colored				Howes—Fully Colored		
	Oct	Nov	Dec	Feb	Oct	Dec	Feb
			CO_2/O_2 Ratios				
30	1.1	0.89	0.76	1.00	0.91	2.78	1.00
35	0.51	0.62	0.55	1.40	0.81	1.56	1.75
50	0.65	0.49	0.91	1.25	1.13	0.86	1.56
Cellar*	0.70	0.84	1.44	1.80	0.94	1.36	3.67
Shed*	0.36	0.52	0.96	1.60	0.75	1.73	2.80
Screenhouse*	0.74	0.74	1.00	1.86	0.86	0.91	2.33
Atwood bog storage*	0.70	0.93	1.08	1.88	0.72	1.48	2.67
			Unsound Cranberries (Per Cent)				
30	None	Very small	6	50	None	4	32
35			8	34		3	38
50			9	38		8	42
Cellar			11	54		9	40
Shed			10	52		8	50
Screenhouse			8	42		7	52
Atwood bog storage			7	40		10	42

Kind of Storage and Temperature (Degrees F)	Early Black—Partly Colored				Early Black—Fully Colored			
	Oct	Nov	Dec	Feb	Oct	Nov	Dec	Feb
			CO_2/O_2 Ratios					
30	0.36	0.29	0.46	0.67	0.35	0.49	0.92	1.29
35	0.27	0.36	0.60	0.60	0.36	0.41	0.67	1.50
50	0.35	0.27	0.66	0.84	0.35	0.50	0.69	1.43
Cellar*	0.28	—	1.17	0.84	0.46	0.99	0.91	2.00
Shed*	0.19	0.44	0.64	0.86	0.38	0.41	0.64	1.22
Screenhouse*	0.84	0.41	0.80	0.73	0.40	0.50	0.64	1.33
Atwood bog storage*	0.30	0.43	0.50	1.00	0.50	0.59	0.79	2.00
			Unsound Cranberries (Per Cent)					
30	None	Very small	24	76	None	5	22	70
35			4	52		5	18	58
50			15	58		5	24	76
Cellar			17	68		5	24	29
Shed			9	44		12	15	62
Screenhouse			13	42		9	32	54
Atwood bog storage			11	44		6	36	42

*The average temperature range in the common storages was 50 to 60 degrees F.

TABLE III—AVERAGE STORAGE LOSSES IN PER CENT FOR TWO SEASONS*

Storage Temperatures: (Degrees F)	30	35	40	45	50	Average of Four Common Storages 50 to 60 Degrees F
Early Black—picked Sep 9:						
Stored Sep 9 to Nov 10	3.9	4.3	3.4	3.3	5.9	11.6
Stored Sep 9 to Nov 30	9.6	4.8	5.9	8.0	9.1	17.8
Early Black—picked Sep 25:						
Stored Sep 25 to Nov 10	4.5	3.4	1.7	3.1	6.9	12.5
Stored Sep 25 to Nov 30	12.8	6.9	4.5	6.3	13.3	20.8
Howes—picked Sep 25:						
Stored Sep 25 to Nov 30	2.7	3.7	3.3	4.4	7.5	10.6
Stored Sep 25 to Jan 31	32.6	13.6	11.5	12.8	19.8	25.9
Howes—picked Oct 15:						
Stored Oct 15 to Nov 30	4.2	2.9	2.5	3.0	6.1	7.1
Stored Oct 15 to Jan 31	17.1	14.5	12.2	10.2	19.7	22.1

*Data collected by C. I. Gunness.

Commercial Storage Losses at Different Temperatures

Table III summarizes two years' research on storage losses in cranberries under commercial storage conditions (4, 5). The following conclusions seem to be justified: (a) Minimum storage losses will occur if cranberries are held at 35 degrees F. Extensive sterile breakdown occurs at 30 degrees F. (b) "Green" or partly colored berries can be colored most satisfactorily at about 45 degrees F. (c) Storage losses can be reduced from 5 to 10 per cent by keeping berries at from 35 to 45 degrees F as compared with storage in the ordinary screenhouse at 50 to 60 degrees F. Screenhouse storages have high temperatures during September but during the late fall months, they may carry the fruit fairly satisfactorily.

The practice of holding the storage at 45 degrees F during filling and for a period thereafter gives promise of being good management in that it calls for less refrigeration capacity than if the storage is kept at 35 degrees F from the time the berries are picked.

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Effect of Carbon Dioxide on Apricots and Peaches Under Simulated Transit Conditions

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STUDIES pertaining to the use of carbon dioxide as a supplement to refrigeration under simulated transit conditions have been reported for Bartlett pears (5) and for sweet cherries (6). During the past season additional information has been secured relative to the behavior of peaches and apricots in artificial atmospheres of carbon dioxide at different temperatures and for various periods of storage. The results of these studies are presented in this report.

Most of the published work pertaining to gas storage of peaches and apricots has dealt with the exposure of the fruit to carbon dioxide for relatively short intervals. Brooks *et al.* (4) found the flavor of J. H. Hale peaches unimpaired after storage at 59 degrees F in 48 per cent CO_2 for 40 hours. Apricots at 47 degrees withstood concentrations of CO_2 gas ranging from 42 to 16 per cent for 2 days without unfavorable effects upon flavor. Allen and Smock (1) reported that J. H. Hale and Elberta peaches required 3 days longer to ripen after 6 days storage in 15 per cent CO_2 gas at 65 degrees than air checks held at 45 degrees. Levi cling peaches were tolerant of 11 to 14 per cent CO_2 for 10 days at 45 degrees and required 2 days longer to ripen than did the check lots in air (2). Brooks and co-workers (3) found a marked difference in the carbon dioxide tolerance of peaches at different temperatures. One day's exposure at a given concentration of CO_2 at 77 degrees was likely to produce about the same degree of objectionable flavor as 2 day's exposure at 59 degrees, 3 day's at 50 degrees, or 4 day's at 41 degrees. Either lack of flavor or off-flavor usually resulted when Belle or Elberta peaches were held in 25 per cent or more of CO_2 at 50 to 68 degrees for 24 hours or longer. The effect of gas treatment upon firmness and inhibition of decay was pronounced.

MATERIAL AND METHODS

Source of Fruit:—Moorpark apricots were secured on July 18 at the time of harvest from an orchard in the Colockum district at Wenatchee, Wash. The fruit was considered of average maturity for commercial shipping, with a firmness of 12.2 pounds pressure (United States Department of Agriculture pressure tester with 5/16 inch plunger and unpeeled fruit). The soluble solids, measured with a Zeiss refractometer, averaged 8.2 per cent.

J. H. Hale and Elberta peaches were secured from a commercial packinghouse. The fruit was picked at the stage of maturity used commercially for distant shipment, and up to the time of placement under experimental storage, was handled in an identical manner with fruit being shipped. This included an overnight cooling period while the fruit was in field boxes in a room held at approximately 40 degrees F. Both varieties of peaches were obtained from two different orchards wherein the time of maturity was the principal variant. One series of

fruit came from an early crop near Malaga, Washington, and the other came from a later crop in the vicinity of Wenatchee. The fruit from each orchard was well matured and possessed some yellow color at harvest. Other data at harvest follow:

Orchard	Variety	Date Harvested	Firmness* (Pounds)	Total Solids (Per Cent)
Malaga	J. H. Hale	August 20, 1940	13.9	11.0
	Elberta	August 20, 1940	14.2	11.5
Wenatchee	J. H. Hale	August 25, 1940	12.2	12.5
	Elberta	August 25, 1940	11.6	11.0

*U. S. Department of Agriculture pressure tester using a 5/16 inch plunger on the peeled fruit.

Storage Procedure:—Well composited samples of 30 fruits each were held at storage temperatures of 45 degrees F, 36 degrees, and 31 degrees for various intervals. The check lots were given free access to the storage air and the others were held in 5, 10, and 20 per cent carbon dioxide. The artificial atmospheres were maintained in metal chambers with water-sealed lids by adding the required gas and by daily adjustment to the required concentration. The relative humidity of the air in these chambers may have been somewhat higher than that of the storage rooms which were maintained at approximately 85 per cent.

Ripening and Quality Observations:—After certain intervals (usually 5 and 10 days) representative lots of fruit were removed to a ripening room held at 65 degrees F and 85 per cent relative humidity. Variation in this procedure occurred only in the case of peaches from the Wenatchee orchard wherein ripening proceeded at 76 degrees and at a somewhat lower relative humidity. Changes in degree of ripening within the different lots of fruit were followed by daily organoleptic examination of the dessert quality, as measured by texture and flavor. Visual inspection included color changes in the tissue and the presence or absence of storage injury as manifested by discoloration of the flesh.

Results

The data pertaining to apricot storage are presented in Table I. After 5 days storage at 45 degrees F all lots of fruit ripened with juicy texture, good flavor, and no discoloration of the tissue. Fruit held in 10 and 20 per cent CO_2 gas required from 1 to 2 days longer to ripen to prime dessert quality than that held in air or in 5 per cent gas.

After 10 days storage at 45 degrees F, only the sample held in air ripened normally. Those lots held in 5, 10, and 20 per cent CO_2 ripened abnormally; the flesh remained pale apricot in color, became very mealy in texture, flat, and insipid in flavor, and in all concentrations of CO_2 gas, showed hydrated discolored areas adjacent to the pit. This type of visual injury is shown in Fig. 1. The severity of this type of injury did not vary with the concentration of the CO_2 gas in the storage air, since at 5 per cent injury was as prevalent as at 20 per cent. In a preliminary storage experiment involving a wide range in harvest maturity (pressure test 17.6 to 5.2 pounds and total solids 7.8 to 11.5 per cent), all lots of Moorpark apricots showed a similar tissue dis-

TABLE I—EFFECT OF CARBON DIOXIDE GAS STORAGE ON MOORPARK APRICOTS AS INFLUENCED BY CONCENTRATION OF THE GAS, TEMPERATURE AND LENGTH OF STORAGE

CO_2 (Per Cent)	Days to Ripen at 65 Degrees F	Quality When Ripened			Visible Injury
		Texture	Flavor	Flesh Color	
Temperature 45 Degrees F, Storage Period 5 Days					
0	3	Juicy	Good	Deep apricot	None
5	4	Juicy	Good	Deep apricot	None
10	5	Juicy	Good	Deep apricot	None
20	5	Juicy	Good	Deep apricot	None
Temperature 45 Degrees F, Storage Period 10 Days					
0	3	Juicy	Fair	Apricot	None
5	3	Very mealy	Poor	Pale apricot	Tissue discolored at pit
10	3	Very mealy	Poor	Pale apricot	Tissue discolored at pit
20	3	Very mealy	Poor	Pale apricot	Tissue discolored at pit
Temperature 36 Degrees F, Storage Period 5 Days					
0	4	Juicy	Good	Deep apricot	None
5	5	Juicy	Good	Deep apricot	None
10	5	Juicy	Good	Deep apricot	None
20	5–6	Juicy	Good	Deep apricot	None
Temperature 36 Degrees F, Storage Period 10 Days					
0	3	Juicy	Fair to good	Deep apricot	None
5	4	Juicy	Fair to good	Deep apricot	None
10	5	Juicy	Good	Deep apricot	None
20	5	Juicy	Good	Deep apricot	None

coloration at the pit after 10 days storage at 45 degrees in either 5, 10, or 20 per cent carbon dioxide. Maturity at harvest, therefore, was not correlated with this injury.

As shown in Table I, Moorpark apricots had a greater tolerance of carbon dioxide gas at 36 than at 45 degrees F. Even following 10 days storage no injury was observed and all gas-stored lots at 36 degrees ripened normally. In general it required from 1 to 2 days longer for the lots in 10 or 20 per cent gas to ripen to best dessert quality than for those held in air or in 5 per cent carbon dioxide.

Firmness and degree of color change during storage are not shown in Table I, but in general it may be stated that 20 per cent CO_2 gas at 45 degrees F produced changes similar to air storage at 36 degrees. Fruit held in 20 per cent gas at 36 degrees came out of storage considerably firmer and greener than comparable lots held in 5 and 10 per cent CO_2. Likewise, these latter lots were not as far advanced in ripening as those in air storage at 36 degrees.

The data pertaining to the ripening of J. H. Hale and Elberta peaches after being stored in air and in various concentrations of carbon dioxide are summarized in Table II.

Both varieties of peaches were firmer and less advanced in color when stored in 10 and 20 per cent CO_2 than when held in air at the same temperature. It usually required from 1 to 2 days longer for the gas-stored lots to ripen to best dessert quality. Furthermore, the effects of gas storage were somewhat more pronounced at storage temperatures of 45 degrees than at 36 degrees F.

In atmospheres carrying 10 and 20 per cent CO_2 at 45 degrees F, the ripening rate of both J. H. Hale and Elberta peaches was retarded to

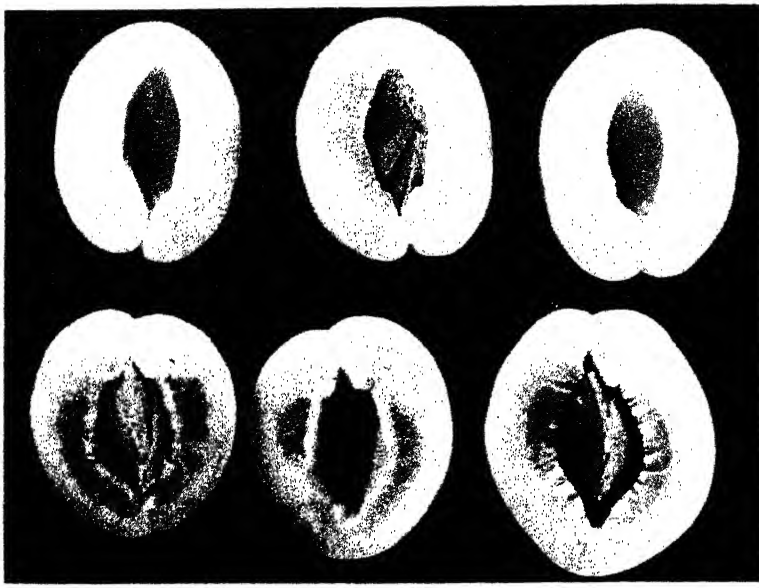

Fig. 1. Tissue injury of Moorpark apricots following storage at 45 degrees F in 5, 10, or 20 per cent carbon dioxide gas for 10 days. Upper row, air storage; lower row, gas storage.

a degree comparable to that in air at 36 degrees. Likewise, similar concentrations of gas at 36 degrees retarded ripening to an extent comparable to air storage at 31 degrees. In no case did the use of carbon dioxide as recorded in Table II result in abnormal ripening as judged by lack of juiciness, prevention of color change, or development of off-flavors. Injury or discoloration of the flesh of the fruit, as shown in Fig. 1 for apricots, was not observed in any of the gas-stored lots of peaches. Elberta and J. H. Hale peaches, therefore, possess a greater tolerance of carbon dioxide than do Moorpark apricots.

After peaches from the Wenatchee orchard were held in the ripening room at 76 degrees F for 6 days, both J. H. Hale and Elberta which had been stored in 20 per cent CO_2 were slightly firmer but possessed no better flavor than check lots held in air storage. In fact, after this long an exposure to 76 degrees the flavor of both varieties stored at 31 degrees in air was slightly better than that of any of the gassed lots. It was not possible to detect any beneficial "residual effect" from the use of carbon dioxide during storage. When such fruit was ripened it did not maintain its prime dessert quality for a longer period than similar lots stored in air.

Discussion and Conclusions

The use of carbon dioxide in the transportation or storage of Moorpark apricots should be attempted with caution. Abnormal ripening of the fruit and break-down or discoloration of the flesh may result

TABLE II—EFFECT OF CARBON DIOXIDE GAS STORAGE ON PEACHES AS INFLUENCED BY CONCENTRATION OF THE GAS, TEMPERATURE, AND LENGTH OF STORAGE

CO_2 (Per Cent)	J. H. Hale (Malaga Orchard)			Elberta (Malaga Orchard)		
	Days to Ripen at 65 Degrees F	Quality When Ripened		Days to Ripen at 65 Degrees F	Quality When Ripened	
		Texture	Flavor		Texture	Flavor
Temperature 45 Degrees F, Storage Period 5 Days						
0	3	Juicy	Good	5	Juicy	Fair
5	3	Juicy	Good	5	Juicy	Fair
10	5	Juicy	Good	7	Juicy	Fair
20	5	Juicy	Good	7	Juicy	Fair
Temperature 45 Degrees F, Storage Period 10 Days						
0	3	Slightly mealy	Fair to poor	3	Slightly mealy	Fair to poor
5	3	Slightly mealy	Fair to poor	3	Slightly mealy	Fair to poor
10	3–4	Fairly juicy	Fair to poor	4	Fairly juicy	Fair to poor
20	3–4	Fairly juicy	Fair to poor	4	Fairly juicy	Fair to poor
Temperature 36 Degrees F, Storage Period 5 Days						
0	5	Juicy	Good	7	Juicy	Fair
5	5	Juicy	Good	7	Juicy	Fair
10	6	Juicy	Good	7–8	Juicy	Fair
20	6	Juicy	Good	7–8	Juicy	Fair
Temperature 36 Degrees F, Storage Period 10 Days						
0	4	Fairly juicy	Fair	4	Fairly juicy	Fair
5	4	Fairly juicy	Fair	4	Fairly juicy	Fair
10	4–5	Fairly juicy	Fair	4	Fairly juicy	Fair
20	4–5	Fairly juicy	Fair	4–5	Fairly juicy	Fair
Temperature 31 Degrees F, Storage Period 5 Days						
0	6	Juicy	Good	7–8	Juicy	Fair
Temperature 31 Degrees F, Storage Period 10 Days						
0	4–5	Fairly juicy	Fair	4–5	Fairly juicy	Fair
CO (Per Cent)	At 76 Degrees F	J. H. Hale (Wenatchee Orchard)		At 76 Degrees F	Elberta (Wenatchee Orchard)	
Temperature 45 Degrees F, Storage Period 10 Days						
0	2	Juicy	Good	2	Juicy	Fair to good
5	2	Juicy	Good	2	Juicy	Fair to good
10	4	Juicy	Good	4	Juicy	Fair to good
20	4	Juicy	Good	4	Juicy	Fair to good
Temperature 36 Degrees F, Storage Period 10 Days						
0	4	Juicy	Good	4	Juicy	Fair to good
5	4	Juicy	Good	4	Juicy	Fair to good
10	5	Juicy	Good	4	Juicy	Fair to good
20	5	Juicy	Good	5	Juicy	Fair to good
Temperature 31 Degrees F, Storage Period 10 Days						
0	5	Juicy	Very good	5	Juicy	Fair to good

from the limited tolerance of apricots for carbon dioxide gas. Correct temperature and length of storage are more vital to successful results than are maturity of the fruit or concentration of the gas. At 45 degrees F the fruit could be held in 20 per cent carbon dioxide gas for 5 days without injury to flavor, tissue, or ripening capacity. Unfavorable results should be expected following the use of as little as 5 per cent gas if the storage period is extended to 10 days. At 36 degrees Moorpark apricots tolerate concentrations of 20 per cent carbon dioxide for a period of 10 days. Fruit stored under these conditions required

approximately 2 days longer to acquire optimum dessert quality than check lots held in air storage.

J. H. Hale and Elberta peaches were tolerant to concentrations of carbon dioxide as high as 20 per cent for a period of 10 days at temperatures of either 36 or 45 degrees F. Gas concentrations of 10 and 20 per cent effectively retarded color development and softening during storage. This retardation was generally more significant at 45 than at 36 degrees. Storage in 20 per cent gas at 45 degrees was similar to that in air at 36, while at the latter temperature a like concentration of CO_2 approximated the results obtained with air-storage at 31 degrees. While it usually required from 1 to 2 days longer for the gas-stored fruit to attain optimum dessert quality than for similar lots held in air, the length of time that such fruit remained in prime dessert quality was not significantly different from that stored in air. In other words, there was no apparent "residual effect" from the use of carbon dioxide gas that would lengthen the period over which the ripened fruit could be consumed.

If a temperature of 36 degrees F could be maintained in refrigerator cars, the use of carbon dioxide during shipment of peaches would not be justified. With temperatures of approximately 45 degrees prevailing in transit, the use of this gas in concentrations of 10 to 20 per cent might permit peaches to be shipped when harvested at a more mature stage. Should the use of gas not be feasible, approximate results could be attained by precooling the fruit to 31 degrees and maintaining the transit temperature as near to 36 degrees as possible by the use of ice and salt.

Should it appear desirable to use solid carbon dioxide in the shipment of peaches, these studies indicate that no detrimental effects upon flavor or ripening of J. H. Hale or Elberta varieties would occur provided conditions in the refrigerator cars did not vary greatly from those in this investigation.

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Further Studies Relating to the Effects of Certain Waxing Treatments on the Subsequent Storage Quality of Grimes and Golden Delicious Apples[1]

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THE results of preliminary work on the effects of waxing Grimes Golden and Golden Delicious apples in relation to subsequent wilting and scald development in storage have been previously reported (2).

This report presents the results of additional studies on the effects of waxing with Brytene 289 and 289 AR, in 1939, diluted with two parts of water on these two varieties, particularly when pre-ripened (held at 60 degrees F) for various periods before placing in cold storage.

Methods

Although the methods used in 1938 have been previously reported (2), they are repeated here since the study was not complete at the time of that report. For the sake of brevity, additional studies on the previously reported Grimes samples from the University orchard are not reported here.

At weekly picking intervals about 3 bushels of each Grimes and Golden Delicious were selected from two commercial orchards. On the day of picking all fruits were hauled into the laboratory where they were divided into eight equal and randomized lots, and were packed in ½ bushel open hampers for cold storage after receiving the following treatments: 1, Waxed on day of picking; 2, not waxed; 3, held 1 week at 60 degrees F, then waxed; 4, held 1 week at 60 degrees F, not waxed; 5, held 2 weeks at 60 degrees F, then waxed; 6, held 2 weeks at 60 degrees F, not waxed; 7, held 3 weeks at 60 degrees F, then waxed; 8, held 3 weeks at 60 degrees F, not waxed.

To follow the weight changes under the different treatments, 10 apples of each lot were marked and weighed for each picking date at the time of the waxing treatments, or when the samples were placed in storage. To remove any effect of unequal storage periods, fruits of each treatment from the different picking dates were left in storage the same number of weeks before grading or additional weighings. These weighings were made 5, 12, 21 and 24 weeks after picking. The grading was done 21 and 24 weeks after picking and consisted of a determination by number of all wilted, scalded and rotted fruits. Following the grading at 21 weeks the unblemished or perfect apples were placed in a storage room at 60 degrees F, and after 3 weeks the fruits were again weighed and graded. Weight losses were calculated in grams per 1,000 grams of the original weight of the 10 marked apples.

The procedure for the 1939 studies was very similar to that employed in 1938. At four picking dates Grimes Golden apples were

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TABLE I—WEIGHT LOSS AT THE STORAGE EXAMINATIONS FOR WAXED AND UNWAXED GRIMES GOLDEN AND GOLDEN DELICIOUS APPLES GIVEN VARIOUS PRE-RIPENING TREATMENT BEFORE STORAGE (1938)

Treatment	Weight Lost in Grams Per 1,000 Grams Original Weight				
	End of Pre-Ripening Period	End of 5 Weeks	End of 12 Weeks	End of 21 Weeks	End of 24 Weeks
Grimes (Orchard 2)					
Waxed immediately	———	15.6±1.7	29.5± 2.8	42.9± 4.3	60.4± 9.2
Not waxed	———	29.0±4.0	48.7± 8.7	73.5±12.6	95.6±18.2
Pre-ripened 1 wk, waxed	11.2±4.9	22.2±5.6	5.2± 6.4	45.7± 5.3	60.6±13.1
Pre-ripened 1 wk, not waxed	11.2±4.9	29.2±4.6	47.7± 7.9	67.6±16.2	88.4±20.7
Pre-ripened 2 wk, waxed	19.0±4.3	27.4±5.2	38.8± 6.4	51.6± 7.2	66.9±10.8
Pre-ripened 2 wk, not waxed	19.0±4.3	31.0±5.1	49.4± 7.7	76.1±19.1	95.6±19.5
Pre-ripened 3 wk, waxed	26.4±2.7	31.4±3.0	47.2± 8.8	59.3± 8.	70.6±10.2
Pre-ripened 3 wk, not waxed	26.4±2.7	32.0±4.4	50.7±10.0	74.6±13.	87.25±19.3
Golden Delicious					
Waxed immediately	———	23.6±2.6	44.9± 4.4	68.5± 7.2	———
Not waxed	———	34.8±2.3	63.5± 4.8	98.3± 7.9	———
Pre-ripened 1 wk, waxed	14.9±2.8	31.3±1.5	51.4± 2.0	75.2± 1.9	———
Pre-ripened 1 wk, not waxed	14.9±2.8	39.5±0.3	67.1± 3.2	105.7±10.9	———
Pre-ripened 2 wk, waxed	———	———	———	———	———
Pre-ripened 2 wk, not waxed	———	———	———	———	———
Pre-ripened 3 wk, waxed	35.9±4.3	41.8±5.1	62.7± 9.2	86.4±10.9	———
Pre-ripened 3 wk, not waxed	35.9±4.3	44.2±5.8	72.2± 9.4	109.45±14.4	———

obtained from the same commercial orchard and the same methods of packaging and determining weight changes were followed. To determine the influence of delays of less than 1 week before waxing upon subsequent scald development, duplicate lots of apples were given the following treatments: 1, Waxed: immediately after picking, and after 2, 4, and 7 days of pre-ripening at 60 degrees F; (duplicate samples were placed in cold storage the day of waxing). 2, Not waxed: duplicate samples were placed in cold storage immediately after picking and after 2, 4, and 7 days of pre-ripening at 60 degrees F. Storage conditions were also slightly different than in 1938.

During the latter part of December the refrigerating machine developed trouble and for approximately a week the temperature of the room reached 45 to 50 degrees F. Since the storage room is of the forced draft type, there was very little air movement when the machinery ceased operation, and conditions favoring prevalence of storage scald existed. These abnormal conditions, however, inadvertently permitted a more significant analysis of the influence of the wax treatments upon severity of scald than would otherwise have been encountered. Following the storage period these apples were weighed and graded as described previously, with the exception that apples showing both wilt and scald were counted in a category separate from either wilted or scalded fruits so they could be considered with either. After grading, the fruit was again exposed to the higher temperatures as in 1938, but additional grading was not done because of the poor condition of all samples.

To determine the efficacy of the wax when used with commercial packages, standard packed bushel baskets of Golden Delicious were selected September 20, 1939 from a commercial packing house and given the following comparative treatments:

Treatment and Storage

Treatment and Storage	*No. Bushels*
Placed at 60 degrees F when packed; waxed before 60 degrees F storage	2
Placed at 60 degrees F when packed; not waxed before 60 degrees F storage	2
Pre-ripened 1 week at 60 degrees F; waxed before cold storage	4
Pre-ripened 1 week at 60 degrees F; not waxed before cold storage	2
Pre-ripened 2 weeks at 60 degrees F; waxed before cold storage	4
Pre-ripened 2 weeks at 60 degrees F; not waxed before cold storage	2
Pre-ripened 3 weeks at 60 degrees F; waxed before cold storage	4
Pre-ripened 3 weeks at 60 degrees F; not waxed before cold storage	2
Placed in cold storage when packed; waxed before cold storage	3
Placed in cold storage when packed; not waxed	4

Baskets from common storage were graded after 6 weeks at 60 degrees F, and the cold storage samples were graded in January. Grading consisted of the segregation of rots, wilted and good fruits from each basket. Each portion was weighed, and separate baskets of identical treatment were considered as replicates.

Results

The weight changes for the Grimes Golden and Golden Delicious for 1938 are given for the entire storage season in Table I. The significance of the wax treatment is more clearly revealed in the analysis of variance summaries in Table II. The value of the wax in reducing weight loss during the 3-week period following removal from cold storage is particularly important and is of statistical significance as

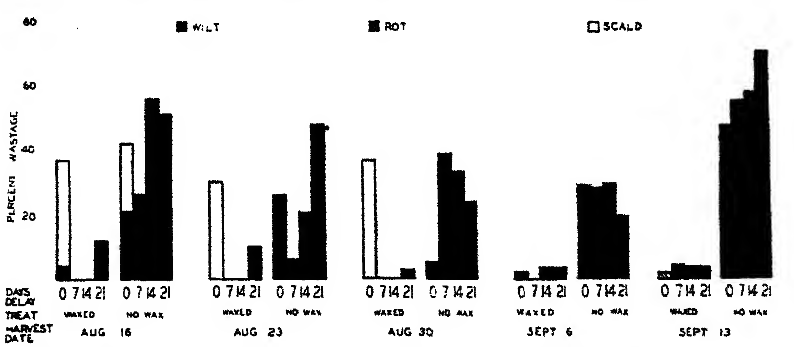

FIG. 1. Grimes Golden 1938. Per cent wastage of waxed and unwaxed fruit when given various pre-ripening treatments at time of harvest followed by cold storage for 21 weeks from date of picking.

TABLE II—WEIGHT LOSSES IN GRAMS PER 1,000 GRAMS ORIGINAL WEIGHT, AT VARIOUS EXAMINATIONS OF GRIMES GOLDEN DURING 1938 RESULTING FROM CERTAIN TREATMENTS FOLLOWING HARVEST AND TESTS FOR THEIR SIGNIFICANCE

Treatment	Mean Loss* (Grams)	Necessary for Significance 5 Per Cent	Necessary for Significance 1 Per Cent	Treatment	Mean* Loss (Grams)
After 21 Weeks From Picking					
Waxed	40.2	19.1	27.2	Harvest Date**	
Not waxed	71.2				
				Aug 14	56.6
				Aug 23	51.7
No pre-ripening	57.6	14.1	19.2	Aug 30	48.8**
Pre-ripen 1 week	56.6			Sep 6	60.0
Pre-ripen 2 weeks	64.1			Sep 13	70.9
Pre-ripen 3 weeks	62.6			Sep 23	73.3
After 24 Weeks From Picking					
Waxed	64.8	20.6		Harvest Date†	
Not waxed	91.9			Aug 14	72.0
				Aug 23	66.1
No pre-ripening	78.0	14.8			
Pre-ripen 1 week	74.8			Aug 30	63.4†
Pre-ripen 2 weeks	81.3			Sep 6	77.8
Pre-ripen 3 weeks	79.2			Sep 13	91.8
				Sep 23	99.1
Weight Loss for 3 Weeks at 60 Degrees F Following Cold Storage					
Waxed	15.6	4.3		Harvest Date‡	
Not waxed	20.2				
				Aug 14	15.1
				Aug 23	14.0
No pre-ripening	20.0	6.7		Aug 30	14.4
Pre-ripen 1 week	17.9			Sep 6	17.7‡
Pre-ripen 2 weeks	17.3			Sep 13	20.5
Pre-ripen 3 weeks	16.3			Sep 23	25.5

* Differences secured by analysis of variance.
** Necessary for significance: 5 per cent, 10.5; 1 per cent, 15.7.
† Necessary for significance: 5 per cent, 12.1.
‡ Necessary for significance: 5 per cent, 2.8.

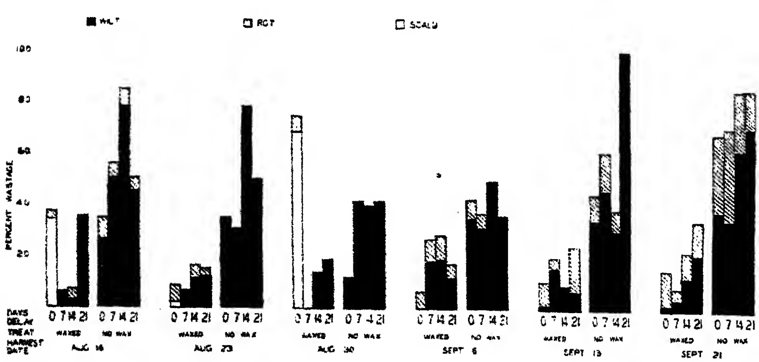

FIG. 2. Grimes Golden 1938. Per cent wastage of waxed and unwaxed fruit when given various pre-ripening treatments at time of harvest, followed by cold storage for 21 weeks from date of picking and thereafter held at 60 degrees F for 3 weeks, to simulate market conditions after storage.

TABLE III—WEIGHT LOSSES, IN GRAMS PER 1,000 GRAMS ORIGINAL WEIGHT, AT THE END OF THE STORAGE PERIODS OF GRIMES GOLDEN AND GOLDEN DELICIOUS RESULTING FROM CERTAIN TREATMENTS FOLLOWING HARVEST AND TESTS FOR THEIR SIGNIFICANCE

Treatment	Mean Loss* (Grams)	Necessary for Significance		Treatment	Mean Loss (Grams)
		5 Per Cent	1 Per Cent		
After 21 Weeks From Picking (Golden Delicious 1938)					
Waxed	76.6	16.6	22.3	Harvest Date**	
Not waxed	103.6				
No pre-ripening	83.4	11.7	15.7	Aug 30	84.8
Pre-ripen 1 week	90.4			Sep 7	83.8
Pre-ripen 2 weeks	88.0			Sep 15	92.7
Pre-ripen 3 weeks	99.0			Sep 24	99.1
After 22 Weeks From Picking (Grimes Golden 1939)					
Waxed	~~4.6~~ 46	~~1.8~~ 18	~~2.4~~ 24	Harvest Date†	
Not waxed	~~7.5~~ 75				
No pre-ripening	~~5.6~~ 56	~~1.3~~ 13	~~1.7~~ 17	Aug 21	~~6.6~~ 66
Pre-ripen 2 days	~~6.3~~ 63			Aug 28	~~7.6~~† 76
Pre-ripen 4 days	~~6.2~~ 62			Sep 4	~~4.6~~ 46
Pre-ripen 7 days	~~6.0~~ 68			Sep 11	~~5.3~~ 53

* Differences secured by analysis of variance.
** Necessary for significance: 5 per cent, 11.7; 1 per cent, 15.7.
† Necessary for significance: 5 per cent, ~~1.3~~ 13; 1 per cent, ~~1.7~~ 17.

shown in the last section of the table. The results of grading are shown in Figs. 1 and 2, and again the effect of the wax in reducing wilt is evident. The 1939 results, presented in Table III and Fig. 3, confirm the observations made in 1938 concerning the efficacy of the wax in reducing weight loss and wilting during storage.

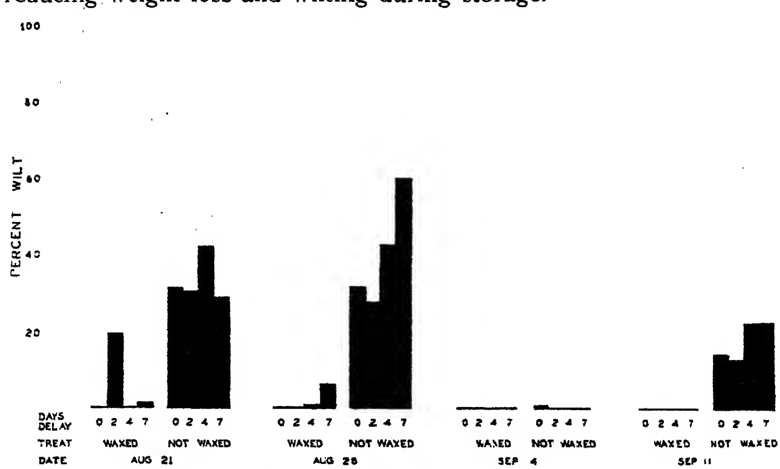

FIG. 3. Grimes Golden 1939. Per cent wilt of waxed and unwaxed fruit when given various pre-ripening treatments at time of harvest followed by cold storage for 22 weeks from date of picking.

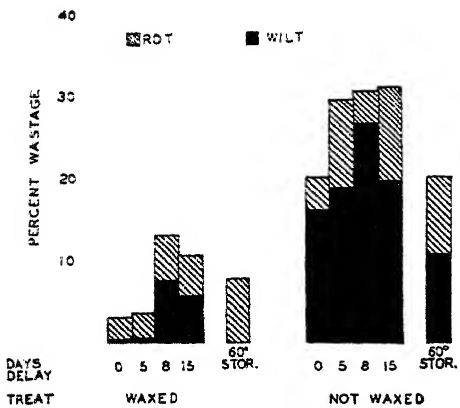

Fig. 4. Golden Delicious 1939. Per cent wastage of waxed and unwaxed fruit when given various pre-ripening treatments at time of commercial packing and followed by cold storage until January 1940.

The effect of the pre-ripening treatments upon weight loss was less marked as the storage season advanced. Although the pre-ripened samples entered storage with a higher initial loss than those stored immediately, these differences at the end of 21 weeks were no longer large. Only in Golden Delicious (Table III) were there any significant differences that can be attributed to delay in storage and then only when the fruits pre-ripened three weeks are compared with the samples stored immediately. As indicated by the data for Grimes Golden in Tables II and III, the pre-ripened periods caused no significant differences in weight loss, and in many cases the samples pre-ripened for one week had a lower weight loss than corresponding samples stored immediately.

With both varieties significant differences between certain dates occurred in every test where more than one picking was made, as indicated by data in Tables II and III. These data indicated that the lowest weight losses during storage occurred with those pickings made in mid-season, whereas higher losses were associated with the earlier and later pickings. Of interest are the larger losses associated with the later picking dates or the more advanced maturity.

The results from the commercially packed Golden Delicious of 1939, as indicated in Fig. 4, show a reduction in wilting in the waxed samples which is of commercial importance. This influence was evident both in cold storage and at 60 degrees F. Although pre-ripening for 2 or 3 weeks materially improved color both in 1938 and in 1939, the practicability of long storage following pre-ripening of more than one week is limited by the increased wastage.

In 1938 pre-ripening Grimes Golden for 1 week at 60 degrees F adequately precluded scald development both during the storage period and after the fruits were removed from cold storage (Figs. 1 and 2). With the abnormal storage conditions which prevailed in 1939 no pre-ripening period was effective in controlling scald. From the results presented in Fig. 5, there is some indication that the longer pre-ripening periods were somewhat more effective for the late picking dates, but the differences were insufficient to have commercial application.

Although the wax retards weight loss and wilting of immediately

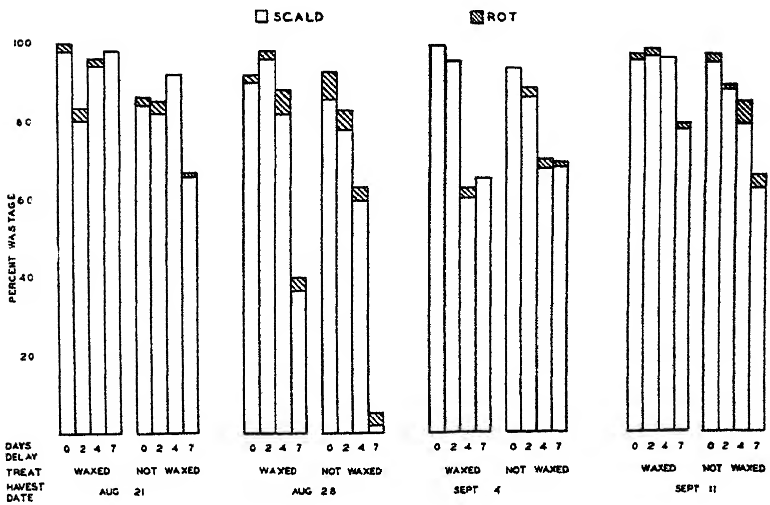

FIG. 5. Grimes Golden 1939. Per cent wastage of waxed and unwaxed fruit when given various pre-ripening treatments at time of harvest followed by cold storage for 22 weeks from date of packing. Excludes wilt except where scald was also present.

stored and pre-ripened apples, certainly at the concentration used in 1939, Brytene 489 AR did not reduce the severity of scald.

DISCUSSION

As revealed by the reduced number of wilted fruits at the time of grading and the decreased weight losses, waxing fruits with the miscible wax materially checked moisture loss under all storage conditions studied.

The reduction in wilted fruits for the Grimes samples picked the first week in September of both years is of interest (Figs. 1, 2 and 3). The increased amount of wastage graded from samples on dates on either side of this harvest date seems to indicate the relatively short picking period at which wilt can be well controlled without supplementary measures. This difference, if loss in premature samples can be attributed to lack of lenticel seal, may be due to the breakage of this sealage by continued fruit growth, as suggested by Clements (1).

Smock (3) suggests that the effect of the wax emulsion upon scald development on Rhode Island Greening is dependent upon fruit maturity, the nature of the emulsion and its concentration. It has been pointed out that both fruit maturity and the pre-ripening period had an influence upon scald on Grimes in 1938 and in 1939, but that the effect was much more important in 1938 than in the following year when storage conditions favored scald development. In both years the increased efficiency of the pre-ripening periods in reducing scald as the fruit became more mature is evident. On both waxed and unwaxed fruits the 1938 results indicate the best method of securing scald control, especially on the most immature samples, is by pre-ripening

for one week or more. Although these pre-ripening periods caused a higher initial loss of weight, the differences were not statistically significant when the whole storage period was considered.

Conclusions

Waxing Grimes Golden apples with Byrtene wax 489A or 489AR significantly reduced the weight loss during the storage seasons of 1938 and 1939. The wax retained its effectiveness in retarding weight changes when the samples were held three weeks at 60 degrees F following 21 weeks in cold storage. The effectiveness of the wax treatments was reflected in the reduced number of wilted fruits graded from Grimes Golden and Golden Delicious at the end of the storage periods.

Waxing the fruit after pre-ripening for 1 week at 60 degrees F adequately precluded development of storage scald in 1938. However, under the abnormal storage conditions of 1939, pre-ripening periods shorter than 1 week had no influence upon scald, and 7-day periods did not adequately control it.

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The Influence of Waxing Seed Potatoes on Loss of Weight, Yield, and Starch Content

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THE senior author in the fall of 1939 determined through a questionnaire that over one million bushels of fruits and vegetables were wax-dipped or wax-sprayed that year.

Limited experimental data with seed potatoes indicates less loss of weight in storage of waxed tubers. Platenius (1) states on the basis of one experiment with seed potatoes that the "rate of shrinkage was reduced somewhat, with a corresponding improvement in appearance". Also that "there is little chance that the waxing process will be adopted for potatoes, except perhaps where they are washed and marketed in consumer packages". Kimbrough (2) in his study of dormancy in potatoes states that "the dormant period should be long enough for the seed pieces to sprout rapidly when planted and the resultant plants to grow vigorously, but not long enough to produce multiple sprouting and stunted early maturing plants".

Reports from commercial research groups indicate that waxing of seed potatoes is accompanied by a slight increase in yield. Limited observations by the senior author on waxing potatoes and vegetables in Rhode Island indicated practically no difference in loss of weight between waxed and unwaxed potatoes in farm cellars.

In order to secure further information along this line an experiment with seed potatoes was started in the fall of 1939 in cooperation with Mr. Hollis Chase of Richmond on whose potato farm the tests were run.

PROCEDURE

On November 20, 1939; 39 5-pound lots of each of the three varieties — Irish Cobblers and Chippewas from Maine and locally grown Green Mountains were carefully weighed. This allowed for three check lots of each variety and three lots of each variety to be treated with Brytene and Dowax each month.

Treatments consisted of dipping the tubers into lukewarm suspensions of 1–2 Brytene 333BO + 1 per cent Sulfocide and 1–4 Dowax, draining for about 10 minutes. Any surplus moisture on the tubers was removed with an electric fan before replacing the samples in storage. Cellar temperatures averaged 42 degrees F, with no more than 2 degrees variation either way. All lots were weighed monthly and notes on sprouting and surface mold were made.

Each lot of potatoes was planted in a 50 foot row on May 6 and 7, using two eyed pieces, hand placed, 1 foot apart. A previous application of 1 ton per acre of a 5–8–10 fertilizer had been placed by the cooperator. The cooperator took care of cultivation and spraying throughout the season. The crop was harvested September 16 and 17 and graded and weighed September 21 and 23, 1940.

The Effects of Waxing on Certain Physiological Processes of the Cucumber under Different Storage Conditions

By Warren B. Mack and Jose R. Janer, *Pennsylvania State College, State College, Pa.*

Abstract

This paper will be published in full elsewhere.

THE effects are described of treatment with wax emulsion on the weight loss, dry matter content, sugar content, respiration rate, respiratory quotient, physiological breakdown, and changes in physical appearance of greenhouse cucumbers stored during 3 weeks in mid-summer in an ordinary room, in a bank cellar, and in cold storage. The most striking differences brought about by wax treatment were reduction in weight loss and spoilage in the ordinary room; increase in pitting in cold storage, a characteristic low-temperature injury on cucumbers; and a significant increase in the respiratory quotient in cold storage, indicating a greater degree of suboxidation.

Fruit Waxing in Relation to Character of Cover[1]

By L. L. Claypool and J. R. King, *University of California, Davis, Calif.*

A GENERAL report of waxing tests with deciduous fruits (1) during the 1939 season showed that some wax emulsions in water were more effective than others even though the same wax percentage was present in each emulsion when the fruit was dipped. In addition to the tests reported, other studies indicated waxes dissolved in volatile petroleum solvents to be effective in reducing water loss on tomatoes, but not on deciduous tree fruits.

The data presented here have as their principal purpose to establish a better understanding of the reasons for differences in water loss and holding and ripening qualities of different fruits when treated with various waxes. In addition to the data previously presented and that included here, considerable information is available on respiration but is not presented at this time.

In order to learn something of the reasons why variable results are obtained with different waxes and with different fruits a study was initiated during the 1940 season relative to the type of surface exhibited by several different fruits and the type and thickness of coverage of the wax film. The four fruits used, namely Royal apricot, Stanwick nectarine, Winter Nelis pear and Pritchard tomato, all have characteristic structural differences in their surfaces which are important insofar as exchange of gases and waxing are concerned. The surface of the apricot is covered with a mat of hairs and there is a high proportion of stomata to lenticels. There are no surface cracks around the lenticels. The surface of the nectarine is contrasted to that of apricot not only by the lack of a definite mat of hairs, but also by a considerable replacement of stomata by lenticels. Frequently, two or more lenticels on nectarine fruits will unite to form one large, irregular opening. This condition is accompanied by the presence of many cracks that extend in all directions and which penetrate below the epidermis. The cracks are perhaps due to stresses and strains accompanying fruit maturity.

The surface of the Winter Nelis pear presents a wide variation in structure. The non-russet areas are smooth with an overlying layer of cutin, but punctured frequently with large lenticels, which may commonly unite to form large and irregularly shaped eruptions. The widespread formation of cork together with the presence of lenticels in the russet areas give a jagged and irregular surface which is difficult to cover completely with any substance. In the mature fruit the stomata are mostly replaced by lenticels.

In contrast to the surfaces of pear, apricot and nectarine, that of the Pritchard tomato fruit is smooth in its entirety. There are no lenticels or stomata, and respiration gas exchange takes place largely or entirely through the stem end. Transpiration is largely cuticular.

Waxes used in these tests were all commercial preparations and

[1]The authors wish to acknowledge the assistance of Dr. R. M. Keefer, of the Chemistry Division, in making the surface tension measurements.

were supplied by the manufacturers or their agents. Water wax emulsions were all applied by dipping after diluting the stock solutions with distilled water to obtain the desired wax concentration.

The waxes contained the following approximate proportions of wax and other materials that may directly affect exchange of gases:

TABLE I—COMPARATIVE WAX COMPOSITION OF EMULSIONS AND SOLUTIONS

Code Letter	Carnauba	Paraffin	Other Materials
A	3	1	———
E	–	1	.18 Mineral oil
F	–	1	———
G	3	1	———
H	–	–	———
I	1	1	.36 Shellac
J	–	1	.75 Spermaceti

The wax coded as J is a solution of paraffin and spermaceti wax in a very volatile petroleum fraction. This material is applied by atomizing the solution into an air blast which is directed on to the rotating fruit.

Specimens of apricot, nectarine, pear and tomato for microscopic study were sectioned with a CO_2 freezing microtome. The sections were stained with a 1 per cent aqueous solution of phyloxine and mounted, after dehydration, in diaphane. By this technic, the wax film was preserved, and its granular nature and deeper staining distinguished it from the cutin. Sections perpendicular to the surface of the fruit were cut from the stem end, the tip, and from two sides of the mid-portion of nectarine; from the tip, the stem end, and one side of the pear and tomato; and from only one side of the mid-portion of the apricot. All observations were made at a magnification of X1350, and measurements of thickness of the wax films were taken with the aid of a Filar micrometer. Observations were also made on the spread of the wax film over the surface of intact, whole fruits.

In determining the effectiveness in covering stomata and lenticels the penetration of the wax into these structures was taken into consideration as well as the surface cover.

The amount of gloss or brightness of finish of the fruit surface is not taken into consideration in this report, although on many fruits a high lustre has considerable sales value.

The data obtained relative to nectarines are omitted since only the solvent type of wax was used with a variation in wax concentration. None of the solutions used gave complete or consistent coverage to the stomata, lenticels or cracks surrounding the lenticels on the surface of the nectarine. It is not surprising, therefore, that very little control of water loss was obtained.

The data for Royal apricots are shown in Table II. The average thickness of the wax film was fairly great, and with two exceptions there was considerable variation in its thickness. The variation in water loss seemed to be related more nearly to the wax type than the film thickness. The paraffin type of wax in general gave better control of water loss even with a thinner film cover than paraffin-carnauba mixtures where carnauba was predominant. There was a tendency for the apricot surface to hold more wax emulsion upon draining than other

TABLE II—RELATIVE EFFECTIVENESS OF WAXES ON ROYAL APRICOTS

Code Letter	Wax Concentration (Per Cent)	Surface* Tension of Wax Emulsion	Average Film Thickness (Microns)	Uniformity† of Wax Film	Effectiveness of Wax in Covering Stomata	Effectiveness of Wax in Covering Lenticels	Water Loss Compared to Control
Control	–	——	—	—	——	——	100
A	4	34.3	3.1	B	Poor	——	51
A	6	33.5	5.0	B	Fair	——	50
G	4	28.7	4.5	B	Fair	Good	55
G	6	29.3	7.1	A	Fair	——	53
E	4	34.2	3.0	B	Good	——	36
E	6	33.1	5.6	B	Excellent	Excellent	29
F	4	34.8	4.9	B	Good	——	43
F	6	34.4	5.5	B	Fair	——	41
H	4	37.9	3.3	A	Fair	——	45
H	6	36.6	4.7	B	Fair	Good	42

*Dynes per square centimeter at 75 degrees F.
†A—Small variability in wax thickness.
B—Large variability in wax thickness.

fruits because of its thick mat of hairs. The film was always greatly thickened at the juncture of a hair with the fruit surface.

As shown in Table III, none of the waxes gave a uniform film coverage on Winter Nelis pears but the average thickness of the film was quite acceptable. Data regarding water loss are not shown as the fruits are still under test. In general, waxes G, E and I have given best results in controlling water loss in other tests with pears. Wax I did not seem to give as good coverage over the lenticels as the other two waxes, but it had a considerable effect in slowing up ripening. Other tests with waxes containing shellac have shown similar results and a reduced respiration rate, indicating interference with oxygen intake. The solvent wax J seemed to give "Fair" coverage, but water loss data on pears indicate that it is rather ineffective.

The data for the tomato in Table IV show only a small variation in the uniformity of the wax cover. However, the average film thickness was less than with other fruits. Water loss control was better again with the paraffin wax than the wax mixtures even with a thinner film. The solvent wax gave better control of water loss in the tomato than with the other fruits. Previous tests with the solvent wax have given a reduction in water loss as much as 50 per cent.

DISCUSSION

There was always some variability in the wax thickness. No coverage appeared uniform throughout, and in the majority of sections

TABLE III—RELATIVE EFFECTIVENESS OF WAXES ON WINTER NELIS PEARS

Code Letter	Wax Concentration (Per Cent)	Surface* Tension of Wax Emulsion	Average Film Thickness (Microns)	Uniformity† of Wax Film	Effectiveness of Wax in Covering Lenticels
A	4	34.3	4.2	B	Fair
G	4	28.7	5.1	B	Excellent
E	4	34.2	4.5	B	Excellent
H	4	37.9	4.3	B	Poor
I	2	——	4.5	B	Poor
I	4	27.8	3.7	B	Poor
J	7	——	3.8	B	Fair

*Dynes per square centimeter at 75 degrees F.
†B—Large variability in wax thickness.

TABLE IV—RELATIVE EFFECTIVENESS OF WAXES ON PRITCHARD TOMATOES

Code Letter	Wax Concentration (Per Cent)	Surface* Tension of Wax Emulsion	Average Film Thickness (Microns)	Uniformity† of Wax Film	Water Loss Compared to Control
Control......	—	——	—	—	100
A...........	4	34.3	4.1	A	88
G...........	4	28.7	4.0	A	71
E...........	4	34.2	2.3	A	58
H...........	4	37.9	2.2	A	—
I...........	2	——	2.4	A	78
I...........	4	27.8	4.1	A	65
J...........	7	——	4.2	A	79

*Dynes per square centimeter at 75 degrees F.
†A—Small variability in wax thickness.

observed, the wax film showed rather wide variability in thickness. Since there was in most cases such great variability and irregularity in coverage by the wax, the average film thickness given in the tables is the average of four measurements from the apparent thickest, the thinnest, and the medium thick areas of the sections observed for each wax film. This average, therefore, is subject to error, but is considered a good comparative estimation. It must be understood, however, that the figure for average wax film thickness is not an indication of the wax film thickness in all areas of a fruit, since some samples of fruits had areas where there was no wax at all, and adjacent areas would have a good film.

There were different expressions of the wax film coverage of stomata and lenticels. The wax film may penetrate a stoma and be present in the intercellular air spaces below the guard cells, as was the case on apricots with a 6 per cent wax emulsion of E, or it may penetrate a stoma only partially. A wax film may penetrate all of the stomata observed, as was again generally true with E, 6 per cent on apricot, or it may cover either no stomata or only a portion of them. Such variation also exists in expression of wax film coverage over lenticels. These different expressions depend upon the kind of fruit and the individual wax films, and all were taken into account in an estimation of the effectiveness of the wax film in covering the stomata and lenticels.

Platenius (2) working on vegetables studied the thickness of the wax film on carrots and found it to vary from 0.5 to 2.7 microns, depending upon the emulsion concentration. These figures are in general somewhat lower than found in any of the fruits reported here. The fact that the data presented by Platenius are calculations on the basis of quantity of wax used, as well as the type of surface being covered, may account for differences in his measurements.

No consistent relationship was observed between surface tension and coverage or water loss control. Evidently the surface tension and wettability of all waxes used was in the effective range for the fruits involved in these tests.

In all tests the type of wax used seemed to be more important than the film thickness. Those emulsions high in carnauba wax gave consistently poorer control of water loss for the same film thickness than

waxes high in paraffin. This was true even though the carnauba waxes seemed to have better wetting ability.

The character of the fruit surface is important in relation to the kind and concentration of wax used. For example, water loss in the apricot, because of the thick mat of hairs over its surface, can be reduced more with a particular emulsion than in the other fruits reported here. Therefore a 2 per cent wax emulsion might be as effective as a 4 per cent in other fruits. The large lenticels increase the difficulty of waxing Winter Nelis pears and nectarines, as also do the corky russet areas of the Winter Nelis pear. In order to effectively reduce water loss on these fruits waxes must be able to penetrate and plug or partially plug the openings in these areas. The tomato is the easiest of the fruits to wax but because of its smooth surface, concentrations of wax emulsions may need to be increased in order to increase the wax film thickness to obtain the desired water loss control. The solvent waxes are of doubtful value for pubescent fruits or those with many lenticels on the fruit surface but give satisfactory results on the smooth surface of the tomato. This may be related to viscosity of the solution at the time it contacts the fruit. The solvent has largely evaporated by that time and the fruit comes out of the spray equipment dry, making the possibility of penetrating stomata and lenticels remote. Less volatile solvents have been tried but cause injury by penetrating through the cuticle and contacting epidermal cells.

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Rate of Development of Reducing Sugar in Cold-Stored Potato Tubers as Related to Time after Harvest at Which Storage was Started

By Norwood C. Thornton and F. E. Denny, *Boyce Thompson Institute, Yonkers, N. Y.*

Abstract

The complete data will be given in a paper that is to appear in the *Contributions from Boyce Thompson Institute.*

POTATOES placed in storage at 5 degrees C soon after harvest accumulated reducing sugar much more rapidly than those held at 25 degrees C for some time after harvest before being placed in storage at 5 degrees C. Russet Rural potatoes placed in 5 degrees C storage 13 days after harvest accumulated 7.3 milligrams of reducing sugar (per cubic centimeter of juice) in 17 days while tubers held at 25 degrees C for 81 days after harvest before being placed at 5 degrees C for the same period accumulated only 0.2 milligram of reducing sugar. This rapidity of accumulation of reducing sugar varied with the variety of potato. Green Mountain potatoes held under the same conditions as the Russet Rural accumulated 13.5 milligrams when placed in storage at the early stage after harvest and only 3.8 milligrams upon low temperature storage after having been held at 25 degrees C for 81 days after harvest before being placed in cold storage.

Dry Matter, Sugar, and Carotene Content of Morphological Portions of Carrots Through the Growing and Storage Season[1]

By H. O. WERNER, *University of Nebraska, Lincoln, Neb.*

CARROTS produced during the hot weather of midsummer in eastern Nebraska generally have a high percentage of core and a generally pale color. Obviously these are undesirable characteristics and a breeding program was set up to develop strains with more desirable characteristics. For such a program it was necessary to have some specific facts about the quality of carrots at various stages in their development throughout an entire growing and storage season.

From plantings of Red Cored Chantenay and Nantes varieties made at Lincoln, Nebraska, in late April, 1937, representative samples of 20 roots were harvested at intervals from July 7 to October 29. Weights of tops and roots were determined. The phloem (including small amount of pericycle) was separated from the xylem. Both portions were weighed and samples taken for dry matter, sugar and carotene determination. On October 30 a large quantity of weighed roots were placed in damp sand in 38 to 40 degrees F storage and 20 root samples were removed for analysis at five periods during the winter with the last sampling on May 31, 1938.

The fresh weight of the phloem always constituted more than 60 per cent of the total root weight, and decreased from highest rate in youngest roots harvested to a much lower percentage late in the season, except for a late summer increase when vegetative growth slowed down. Increase in xylem percentage — that is, decrease in phloem — was associated with rapid vegetative growth. Nantes had a higher percentage of phloem weight than Red Cored Chantenay.

Percentage of dry matter was always greater in the phloem than in the xylem, increased from low values in youngest root to maximum in mid-August, then decreased, was generally higher in Chantenay than Nantes and decreased only slightly in storage (Fig. 1).

The percentage of sucrose in the phloem increased rapidly to a late August maximum, then decreased until late October and in storage through November after which it was relatively constant. The sucrose percentage of xylem was always lower than of the phloem but decreased slightly early in the season when it was increasing in the phloem; then as the latter decreased the percentage in the xylem increased until late October and then decreased slightly. In storage, sucrose percentage of the xylem was greater than that of phloem with Chantenay but not with Nantes. Sucrose percentages were higher in Chantenay than in Nantes except for a brief period early in the season when that of Nantes phloem was greatest (Fig. 2).

Percentages of reducing sugars were highest in xylem throughout the growing season, with greatest difference in two portions in August (when phloem attained the highest percentage of sucrose). Lowest

[1]Published with the approval of the director as Journal No. 279 of the Nebraska Agricultural Experiment Station.

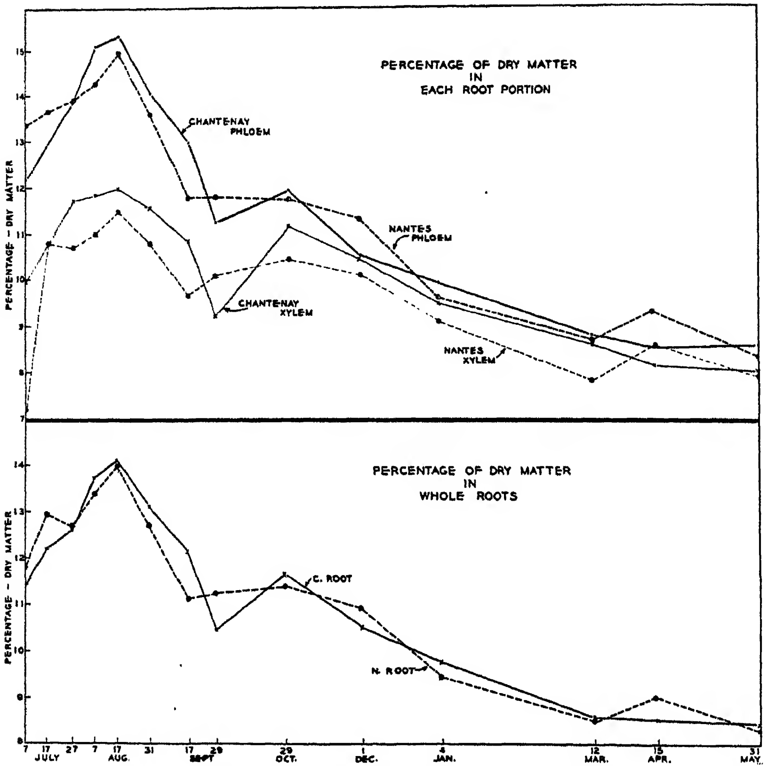

FIG. 1. Percentage of dry matter in each root portion and in total roots of two varieties of carrots when harvested on various dates and at intervals during storage.

reducing sugar percentages occurred in September and October. They increased in storage in both parts of Nantes roots and in phloem of Chantenay but there was no change in Chantenay xylem.

The amount of sucrose in both parts of both varieties exceeded that of reducing sugars throughout the growing season, except for a brief time early in the season when the amount of reducing sugars in xylem was greater than the sucrose. The ratio of sucrose to reducing sugar weight in phloem increased steadily until late August, then decreased rapidly until after about a month in storage when it was less than 1.0 (because of great decrease in sucrose percentage). This ratio declined more with Nantes than with Chantenay. In the xylem there was little difference in amount of sucrose and reducing sugar until early August after which the sucrose/reducing sugar ratio increased steadily until late October due to the reducing sugar percentage decreasing and sucrose percentage remaining about constant. Chantenay xylem had a higher sucrose/reducing sugar ratio than the phloem but the reverse occurred with Nantes.

The sucrose/reducing sugar weight ratios for total roots of both varieties rose slowly until mid-August, then rapidly until late August, then declined slowly until late October, dropping rapidly during the first month of storage, then decreasing slowly. It was almost constantly higher with Chantenay than Nantes.

When sweetness was evaluated on the basis of 100 for sucrose and 74 for reducing sugar (which in carrots is practically all glucose) the phloem had a higher sweetness rating than the xylem throughout the entire growing season. During the period of most rapid root enlargement the sweetness of xylem decreased, increasing rapidly after early August, attaining a sustained maximum with Chantenay in late August and with Nantes in late October. While the sweetness of both root parts decreased rapidly in November storage there was little decrease after that date. In storage the Chantenay xylem was sweetest of any root portion and maintained a high value continually, whereas Nantes phloem lost most sweetness. Chantenay roots were consistent-

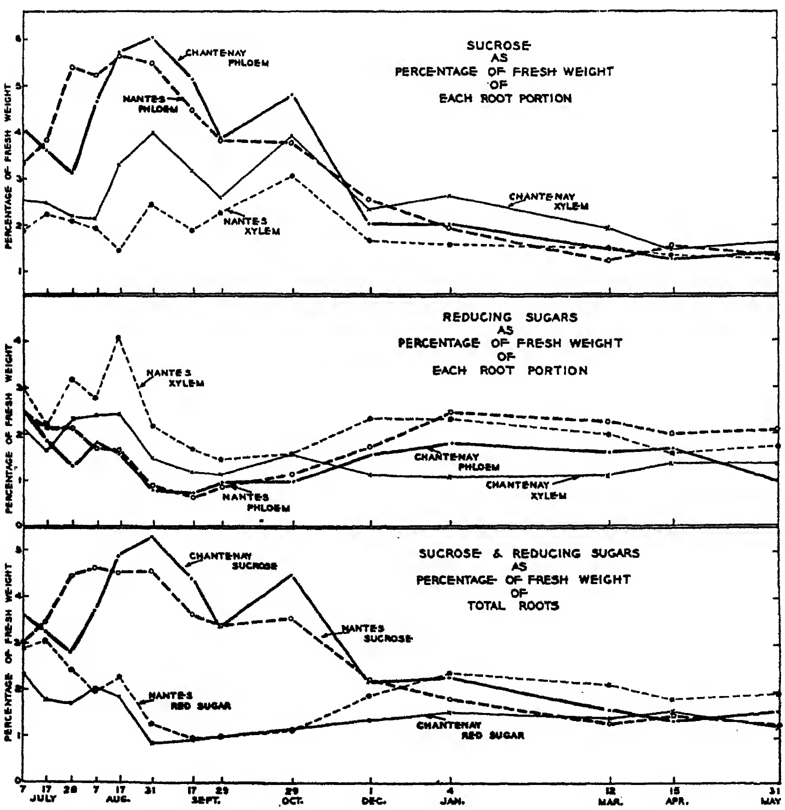

FIG. 2. Percentage of sucrose and reducing sugars in each root portion and in total roots of two varieties of carrots when harvested on various dates and at intervals during storage.

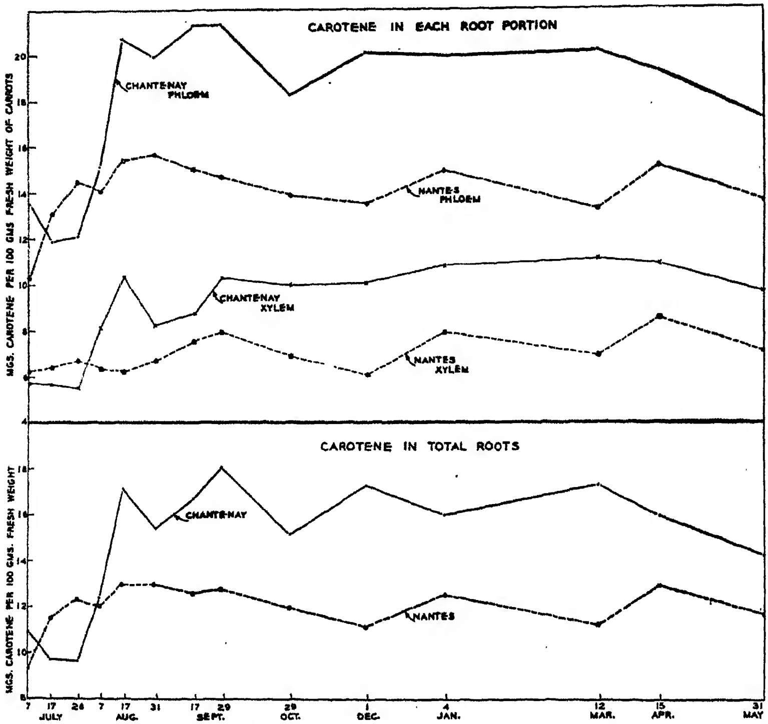

Fig. 3. Carotene content in each root portion and in total roots of two varieties of carrots when harvested on various dates and at intervals during storage.

ly sweeter than Nantes with storage differences increasing above those of the growing season.

Carotene content per given amount of fresh weight was always higher in phloem than in xylem. It attained a maximum value in both root parts by mid-August, (earlier than maximum sweetness was attained) and then remained relatively constant. There was no change in carotene content in storage till sprouts started in the late spring. The carotene content of Chantenay was consistently higher than in Nantes except during the first few weeks when Nantes had the highest sucrose percentage (Fig. 3).

From 70 to 83 per cent of the carotene of Chantenay was found in the phloem in which part occurred 80 to 87 per cent of the Nantes carotene. Lowest percentages of total root carotene occurred in phloem when phloem percentages of total weight were lowest, which was during periods of most rapid growth.

When evaluated on the basis of carotene content and sweetness the phloem was always superior to xylem. Although there were some fluctuations during the growing season, the general tendency was for the relative value of the phloem to diminish as roots became older, due

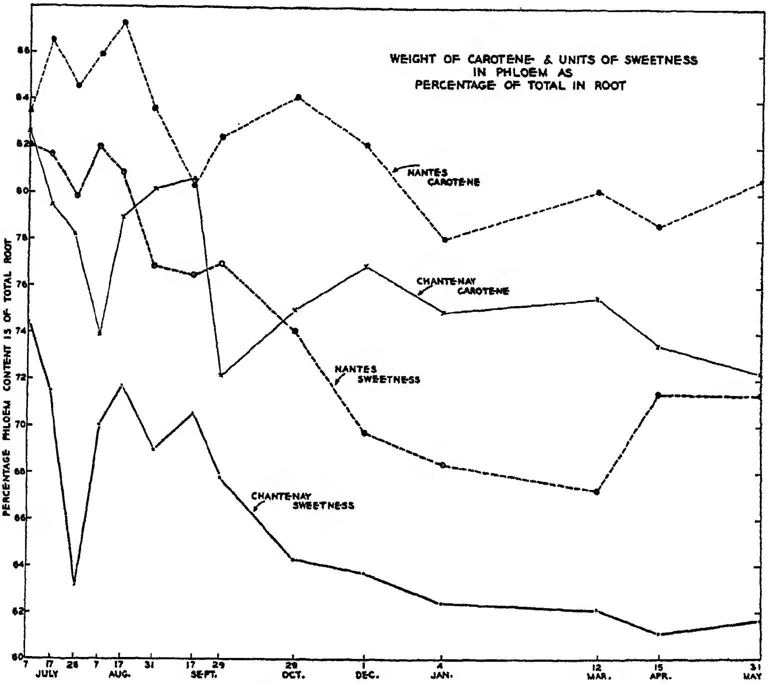

FIG. 4. Weight of carotene and units of sweetness in phloem as percentage of total in roots of two varieties of carrots when harvested on various dates and at intervals in storage. (Sweetness of sucrose calculated as 100, reducing sugar considered as glucose evaluated at 74.)

to less sucrose in the phloem and more in the xylem. In the Nantes variety the phloem was always much more important as a source of quality than in the Chantenay, or stated in reverse — the xylem of the Chantenay became increasingly more valuable as the season advanced (Fig. 4).

In another phase of this project we have determined that there is not only a great difference in the phloem/xylem fresh weight ratios of different varieties but that this

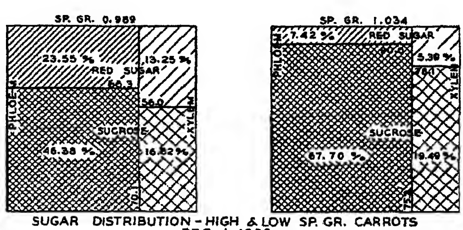

FIG. 5. Percentage of weight in phloem and xylem in low and high specific gravity roots and percentage of each portion that consisted of sucrose or reducing sugars. Percentages on vertical lines indicate percentage that phloem weight was of total weight, those on horizontal lines the percentage that sucrose was of either phloem or xylem and number in center of each area is the percentage that the specified sugar occurring in that root portion is of the total amount of sugar in the root.

ratio can be altered by cultural conditions and that there is a great range of ratios for individual roots within a variety. As grown at Lincoln, roots of late plantings and roots produced on dry land or with a straw mulch had a higher phloem/xylem ratio than those from early plantings, irrigated land or non-straw mulched. Ratios within varieties varied much more for different roots than the mean ratios of varieties. Roots with highest ratios were found to have high specific gravity and they contained the highest percentages of total sugar and of sucrose. From individual high specific gravity roots we have produced progenies with all roots in the higher specific gravity classes while from low specific gravity roots the progenies exhibit a decidedly lower specific gravity. High phloem/xylem ratios exist with the high specific gravity roots and low ratios with low specific gravity roots. The high specific gravity roots generally have better color and more desirable type than low specific gravity roots.

Influence of Time of Harvest on Storage Scald Development of Rhode Island Greening and Cortland Apples

By E. P. Christopher, *Rhode Island Agricultural Experiment Station, Kingston, R. I.*

Abstract

To be published in full as a Circular for the Rhode Island Agricultural Experiment Station.

THREE years data on the development of scald both in storage and after removal from storage gave further evidence of the importance of delayed harvest in reducing the danger of this difficulty on Rhode Island Greening and Cortland apples.

With Greenings, some differences due to season and soil fertility conditions were noted while with Cortland, time of harvest was the only variable factor involved. Apparently any beneficial effects from delayed harvest are more pronounced during the early part of the storage season.

Under the conditions of these tests, delaying harvest of Greenings to late September resulted in greater size, less scald and very little breakdown. Cortland harvested up to mid-October improved in size, color, and freedom from scald both in storage and after removal to room temperature.

The Elapsed Period from Full Bloom as an Index of Harvest Maturity of Pears

By A. Lloyd Ryall, *U. S. Department of Agriculture, Yakima, Wash.;* Edwin Smith, *U. S. Department of Agriculture, Wenatchee, Wash.;* and W. T. Pentzer, *U. S. Department of Agriculture, Fresno, Calif.*

A FEW fruit growers and horticultural field men have recognized for years that there is a rather definite period between the blossoming of fruit trees and the time the fruit is ready for harvest. Records of blossoming dates of the different varieties together with harvest dates have been kept, in a few instances, over a period of years. These records have been valuable to individual growers as a means of planning orchard work to advantage and particularly with respect to meeting labor needs for the harvest period. As experimental evidence, however, the records are of little value since they show merely when harvest was begun and completed rather than at what period the fruit was of optimum maturity from the standpoint of dessert and storage quality.

The relation between date of full bloom and date of harvest of apples was recognized by Magness, Diehl and Haller (4) who stated "Data so far obtained indicate that there is a fairly close relationship between the time of full bloom in different varieties and the best picking date." In the same publication the approximate number of days from bloom to best picking date are given for several apple varieties.

The indices now used for the determination of pear maturity are as follows: firmness as measured by the pressure test, ground color by comparison with the standard color chart, and finish, size, seed development and texture as determined by experience. The index most commonly used for pear maturity (5) is firmness as measured by mechanical means. This index is generally reliable when a truly average figure is compared with desirable ranges as determined by experimental work. It has been demonstrated however (1, 2, 3, 6), that factors such as growing temperatures, evaporating power of the air, kind of rootstock and water supply to the tree can materially affect flesh firmness. Within certain districts such as Medford, Oregon, the pressure tester has indicated a great variation in firmness which, with a variety like Bosc, is very confusing except to persons of long experience in determining pear maturity. In such cases the indices in current use are inadequate in forecasting when a crop may be mature for harvest.

Since additional indices of pear maturity seemed desirable the following experimental work was undertaken in an attempt to ascertain the reliability of the elapsed period from full bloom as an index with different varieties in several different pear producing districts.

Methods

Previous to the blossoming seasons of 1937, 1938 and 1939 trees of the Bartlett, Anjou and Bosc varieties were selected in two locations

in the Yakima and Wenatchee Valleys in Washington. One location in each of the two districts was at a relatively high elevation while the other location was on the floor of the valley. Trees of the three varieties were also selected in the Hood River and the Rogue River Valleys, in Oregon, and during the 1938 and 1939 seasons plots in the Santa Clara Valley in California were added.

Record of full bloom for each variety was kept by observers in each district. For the sake of uniformity the trees were recorded as in full bloom when three to four of the lowest blossoms on each cluster were open and the anthers were shedding pollen. This stage however, was sometimes rather difficult to determine exactly, especially in seasons when the blooms were straggly. As temperature appeared to be the external factor most likely to influence maturity, a thermograph record was kept in each orchard from time of full bloom until the last picking was made.

At the time of each picking firmness was determined by means of the United States pressure tester having a $^5/_{16}$-inch plunger. In arriving at an average figure a sample of 15 fruits was used and each fruit was tested on a peeled surface of two sides. Ground color was determined by means of the United States standard ground color chart for apples and pears. Within a few hours after each picking a box of the fruit was wrapped, packed and placed in storage at 30 to 31 degrees F for later ripening.

After definite storage intervals for each variety, fruits of each picking from each orchard were removed from cold storage and ripened at 65 to 70 degrees F. Observations as to flavor, texture, appearance, shriveling and physiological disorders were made as the pears ripened.

Results

The detailed data pertaining to harvesting, growing temperatures and fruit quality are too lengthy for presentation here. Condensed data showing dates of bloom, firmness of Bartlett pears at harvest, temperature accumulations for definite periods in each district and elapsed period from bloom to different stages of quality in three varieties are shown in Tables I to VI.

Data in Table I show that blossoming was earlier in all districts in 1939 than in either of the two previous seasons. In 1937 the bloom was 12 to 16 days later than in 1939 while bloom in 1938 was somewhat earlier than in 1937 but later than 1939. As would be expected the bloom was earlier each year in the more southerly districts than in the northern districts and earlier at the lower elevations than at the higher elevations.

The firmness of Bartlett pears at definite intervals from bloom for each of the three years is shown in Table II. It is shown in these data that the firmness at 110 days from bloom varied from 16.1 pounds at the upper elevation in the Wenatchee district in 1938 to 23.7 pounds in the Medford district in 1937. The data indicate, however, that within a given district the fruit firmness is rather uniform for different years. For the four locations in the Yakima and Wenatchee Valleys the

TABLE I—THE DATE OF FULL BLOOM IN THREE SEASONS IN EACH OF THE DIFFERENT DISTRICTS

District and Location	Date of Full Bloom								
	1937			1938			1939		
	Bartlett	Anjou	Bosc	Bartlett	Anjou	Bosc	Bartlett	Anjou	Bosc
Yakima (Buena)	Apr. 26	Apr. 23	Apr. 30	Apr. 18	Apr. 16	Apr. 20	Apr. 10	Apr. 8	Apr. 12
Yakima (Lower Naches)	May 1	Apr. 29	May 2	Apr. 24	Apr. 22	Apr. 26	Apr. 15	Apr. 14	Apr. 17
Wenatchee (Lower Valley)	May 1	Apr. 30	May 3	Apr. 24	Apr. 24	Apr. 27	Apr. 18	Apr. 18	Apr. 21
Wenatchee (Wheeler Hill)	May 9	May 7	May 14	May 1	May 1	May 9	Apr. 24	Apr. 24	Apr. 28
Hood River (Lower Valley)	Apr. 25	Apr. 24	Apr. 29	Apr. 21	Apr. 20	Apr. 25	Apr. 9	Apr. 7	Apr. 14
Medford (Lower Valley)	Apr. 19	Apr. 18	Apr. 19	Apr. 16	Apr. 14	Apr. 18	Apr. 3	Apr. 2	Apr. 8
Santa Clara (Santa Clara)	—	—	—	Apr. 12	Apr. 4	Apr. 12	Apr. 7	Apr. 1	Apr. 7

largest spread in firmness at 110 days from bloom is 2.4 pounds. Since the recommended pressure range for fresh market harvest in this district is from 17 to 19 pounds it is evident that fruit from any orchard in these districts in the three years studied was close to the recommended firmness. The data indicate further that the Santa Clara Bartletts were somewhat similar to those from Washington in firmness whereas the Bartletts grown in the Hood River and Medford areas were generally firmer at any given interval. The relationships are quite similar for Bartlett pears at any of the harvest intervals used. The firmness data are of interest in a comparative way but are of little practical value except insofar as they are related to quality of the ripened fruit. Thus, the fact that Bartletts from the Hood River area were firmer at 110 days from bloom than those from the Yakima Valley does not necessarily mean that they were less mature.

Comparative temperature data for the different locations are shown in Table III. Since no definite information was available on the exact temperature factors favoring the growth and maturation of pears

TABLE II—Relation Between Interval from Bloom of Bartlett Pears and Firmness as Measured by Pressure Test

District and Location	Number of Days from Full Bloom										
	100		110			120			130		
	1938	1939	1937	1938	1939	1937	1938	1939	1937	1938	1939
Yakima (Buena)	18.9	20.6	17.1	17.2	18.5	15.2	15.4	16.9	13.0	—	16.0
Yakima (Lower Naches)	19.2	20.3	16.8	17.0	18.5	14.9	14.2	16.9	11.2	—	14.9
Wenatchee (Lower Valley)	20.8	17.1	16.8	17.0	17.0	15.9	15.3	15.1	11.2	13.6	13.3
Wenatchee (Wheeler Hill)	19.1	20.0	18.1	16.1	17.6	15.2	14.2	15.0	8.9	12.0	14.0
Hood River (Lower Valley)	21.1	—	—	20.3	18.7	—	18.1	17.1	—	—	15.1
Medford (Lower Valley)	—	—	23.7	23.6	21.3	21.9	19.7	18.8	16.8	17.3	16.5
Santa Clara (Santa Clara)	18.4*	18.9	—	17.5†	18.2	—	—	14.4	—	—	14.9

*105 days from bloom.
†115 days from bloom.

certain arbitrary standards were used to indicate temperature conditions in the different locations. The total number of degree-hours above a mean of 40 degrees F shows in a general way the heat units available in any given location. These figures are somewhat misleading however, because districts not having extremely high or low temperatures sometimes showed as great an accumulation of degree-hours above 40 degrees F as those where night temperatures were lower and day temperatures were higher whereas the effects on growth of such temperature conditions might be quite different. In order to clarify these temperature influences the number of days on which the maximum temperature reached 90 degrees F or over are shown for the growth periods.

These data show that in each of the three seasons the greatest temperature accumulation occurred in the lower elevation district of the Yakima Valley. The lowest temperature accumulation was in the Santa Clara district in 1938 while in 1939 both Santa Clara and Medford had considerably lower degree-hour accumulations than

TABLE III—COMPARISON OF TEMPERATURE ACCUMULATION FOR THREE SEASONS IN DIFFERENT DISTRICTS

District and Location	110 Days From Bartlett Bloom						120 Days From Bartlett Bloom					
	1937		1938		1939		1937		1938		1939	
	Mean Degree Hours Above 40 Degrees F	Days Max. 90 Degrees F Or Over	Mean Degree Hours Above 40 Degrees F	Days Max. 90 Degrees F Or Over	Mean Degree Hours Above 40 Degrees F	Days Max. 90 Degrees F Or Over	Mean Degree Hours Above 40 Degrees F	Days Max. 90 Degrees F Or Over	Mean Degree Hours Above 40 Degrees F	Days Max. 90 Degrees F Or Over	Mean Degree Hours Above 40 Degrees F	Days Max. 90 Degrees F Or Over
Yakima (Buena)	70,308	37	71,544	32	66,024	22	77,208	42	78,516	33	74,556	29
Yakima (Lower Naches)	62,268	13	70,836	33	61,644	16	68,232	13	76,764	33	70,260	22
Wenatchee (Lower Valley)	64,709	21	63,024	21	63,876	19	70,469	21	69,024	21	71,136	22
Wenatchee (Wheeler Hill)	67,838	8	64,440	11	60,396	12	73,723	8	71,880	14	67,680	12
Hood River (Lower Valley)	54,192	10	60,060	16	—	—	—	—	65,520	16	—	—
Medford (Lower Valley)	56,640	16	62,316	36	51,684	12	63,588	18	69,108	38	60,684	22
Santa Clara (Santa Clara)	—	—	47,868	0	54,288	0	—	—	53,664	0	60,408	0

TABLE IV—THE NUMBER OF DAYS FROM FULL BLOOM TO MATURITY IN THREE DIFFERENT SEASONS (BARTLETT PEARS)

District and Location	Elapsed Period From Full Bloom to Harvest								
	1937			1938			1939		
	Under Mature (Days)	Best* Quality (Days)	Over Mature (Days)	Under Mature (Days)	Best Quality (Days)	Over Mature (Days)	Under Mature (Days)	Best Quality (Days)	Over Mature (Days)
Yakima (Buena)	—	110	130	100	110	Over 120	100	120	Over 130
Yakima (Lower Naches)	—	110	130	100	110	Over 120	100	120	Over 130
Wenatchee (Lower Valley)	—	110	130	Under 100†	110	130	100	120	Over 130
Wenatchee (Wheeler Hill)	—	110	130	Under 100	110	130	100	120 and 130	—
Hood River (Lower Valley)	—	110	140	Under 100	110 and 120	—	110	120 and 130	—
Medford (Lower Valley)	110	125	—	110	130	—	120	140	—
Santa Clara (Santa Clara)	—	—	—	105	125	—	100	120	Over 130

*As determined by flavor, texture and storage life.
†First picking in 1938 season.

the Washington districts. It is apparent from a study of the blossoming dates however, that one reason for the deficiency in temperature accumulation in the Santa Clara and Medford districts was the early bloom. Harvest of Bartlett pears in these early bloom districts was underway before the season of highest temperatures whereas with a later bloom date a greater part of the growing period was under the relatively high temperature conditions of July and August.

Table IV shows the comparative state of maturity of Bartlett pears at different intervals from bloom as judged by dessert and storage quality. As pickings were made at 10 day intervals the number of days shown for best quality may not actually show the interval at which optimum quality occurred since this state may have been reached at some point between the pickings. It does indicate however which of the pickings were judged the most desirable by the above mentioned standards.

In 1937 the first picking of Bartletts was made at 110 days from bloom. As shown in Table IV pears of this picking proved to be the most desirable except in the case of the Medford fruit. Bartletts picked at 130 days in the northern districts showed evidence of being overmature.

In 1938 and 1939 the first picking was made at 100 days from bloom and in all cases the fruit of this picking was less desirable than that picked later. Bartletts picked at 110 days in the northern districts were judged more desirable than those picked earlier or later. In 1939 the best quality Bartletts in the northern districts were obtained at 120 days and in two instances those picked at 130 days were judged equally good. Fruit picked at 100 days was distinctly immature while that harvested at 110 days was not objectionable but did not have as high quality as that picked later.

The data show that the Hood River Bartlett pears required slightly longer to reach desirable maturity than those grown in the Yakima and Wenatchee Valleys. Bartletts grown in the Medford area required distinctly longer to reach maturity than those from any other district studied. It will be noted in Table II that Bartletts grown in the Medford district were also significantly firmer at a given interval from bloom than those from other districts.

Pears of this variety grown in the Santa Clara Valley in 1938 required longer to reach maturity than those grown in the Washington districts while in 1939 the Santa Clara pears required about the same interval.

There does not appear to be any one factor which explains the varying growth periods in different seasons and districts. The fact that the Bartletts generally required longer to reach maturity in 1939 than in 1938 might be due in part to the earlier bloom season of 1939 which resulted in a greater part of the growing period occurring before the maximum temperature period was reached. Data in Table III show that the temperature accumulation in 1939 was lower during the Bartlett growing season than in 1938 in all districts except the

Santa Clara Valley. The Santa Clara district was the only one in which Bartletts did not require longer for maturation in 1939.

On the other hand temperature differences do not appear to explain the longer season required for Medford Bartletts in any given season. While it is true that the temperature accumulation was lower in the Medford area than in the Washington districts it is also apparent that the temperature accumulation was usually somewhat greater in the Medford district than in the Hood River and Santa Clara districts where the growth period more nearly coincided with that of the Washington districts. It appears possible that the distinctly heavy, clay adobe soil of the Medford area may be a factor in the longer period required for fruit maturation.

Table V shows the days from bloom required for certain stages of quality in Anjou pears. These data show that 145 or 150 days were required for best quality in the northern districts with the period quite consistent from year to year. In the Medford district the Anjous required a longer period to reach desirable maturity than in the Hood River and Washington locations. The big spread in days between under maturity and over maturity of Anjou pears in all locations indicates that the harvesting period of Anjou pears within which relatively good quality can be expected is rather long. This does not mean that the Anjou pears were of optimum quality during this entire period. It does indicate however that reasonably good dessert quality and good keeping quality were found over rather an extended picking period.

In Table VI are shown the comparative picking periods for Bosc pears. The data indicate that as with the other two varieties, the elapsed period from bloom to good quality was rather uniform in the northern districts in any one season. The best quality was attained at 130 to 135 days in these districts although pears picked at 145 days were judged equally good in 1939. The Bosc from the Medford district required significantly longer to reach harvest maturity while those grown in the Santa Clara Valley were comparable to the pears grown in the Washington and Hood River districts.

Discussion

The data presented indicate that the elapsed interval from bloom to fruit maturity in pears is quite consistent from season to season in different locations of the same general area but varies somewhat between districts. There are indications in the data that variations encountered were due in part to earliness of bloom and seasonal temperatures and it is suggested that other growth influences such as soil structures, soil moisture and rate of evaporation in the air may have been contributing factors.

From the data secured these variations within a district do not appear great enough from season to season to prevent the practical use of this index in forecasting in advance when a given crop of pears will be satisfactorily mature for harvesting.

It is believed by the writers that the number of days from bloom, when used in connection with firmness, ground color and finish of the

TABLE V—THE NUMBER OF DAYS FROM FULL BLOOM TO MATURITY IN THREE DIFFERENT SEASONS (ANJOU PEARS)

District and Location	Elapsed Period From Full Bloom to Harvest								
	1937			1938			1939		
	Under Mature (Days)	Best* Quality (Days)	Over Mature (Days)	Under Mature (Days)	Best Quality (Days)	Over Mature (Days)	Under Mature (Days)	Best Quality (Days)	Over Mature (Days)
Yakima (Buena)	Under 135†	150	165	125	145	155	135	—	—
Yakima (Lower Naches)	Under 135	150	165	135	145	Over 155	135	145	155
Wenatchee (Lower Valley)	135	150	Over 165	125	145	155	125	145	155
Wenatchee (Wheeler Hill)	Under 135	150	165	125	145	Over 155	125	145	155
Hood River (Lower Valley)	135	150	165	—	145	—	125	145	155
Medford (Lower Valley)	Under 150	165	—	145	155	Over 165	145	155	—
Santa Clara (Santa Clara)	—	—	—	140	150	—	145	165	—

*As determined by flavor, texture and storage life.
†First picking in 1937 season.

TABLE VI—THE NUMBER OF DAYS FROM FULL BLOOM TO MATURITY IN THREE DIFFERENT SEASONS (BOSC PEARS)

District and Location	Elapsed Period From Full Bloom to Harvest								
	1937			1938			1939		
	Under Mature (Days)	Best * Quality (Days)	Over Mature (Days)	Under Mature (Days)	Best Quality (Days)	Over Mature (Days)	Under Mature (Days)	Best Quality (Days)	Over Mature (Days)
Yakima (Buena)	—	130	160	125	135	Over 145	125	135 and 145	155
Yakima (Lower Naches)	—	130	145	125	135	145	125	145	155
Wenatchee (Lower Valley)	—	130	160	125	135	Over 145	125	135 and 145	155
Wenatchee (Wheeler Hill)	—	130	160	Under 125	135	Over 145	125	135 and 145	155
Hood River (Lower Valley)	—	130	160	125	135	Over 145	125	145	155
Medford (Lower Valley)	130	145	—	135	145 and 155	—	135	155	—
Santa Clara (Santa Clara)	—	—	—	125	145	—	125	135	155

*As determined by flavor, texture and storage life.

fruit will be a valuable adjunct to present indices in determining the proper harvest period for pears in the western pear producing areas.

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Some Factors Affecting the Storage Quality of the Cortland Apple[1]

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THE Cortland apple originated at the New York Agricultural Experiment Station as a cross between Ben Davis and McIntosh in 1898. The hardiness of the variety and the average high yields indicate that it is fairly well adapted to the fruit-growing regions of northeastern United States. Its storage behavior suggests that it must be carefully grown, making use of an intelligent program of fertilization and pruning as well as judgment as to the proper time of harvest. A study of some of these factors, particularly the relation of climatic and cultural conditions and maturity of the fruit to the storage quality of this variety, was made over a 6-year period from 1934 to 1939.

METHODS AND PROCEDURE

The greater part of the fruit used in this storage study was taken from one of the Cornell University orchards located at Ithaca, New York. This orchard, planted in the spring of 1928, was set 10 by 10 on the square system. There were 80 rows in the original planting, each with 40 trees. Every other row was removed in 1936 and every other tree in the remaining rows was cut out in 1938. The topography of this block is gently rolling with the tendency to slope toward the southeast. The soil is classified as Dunkirk silty clay loam and is quite variable especially in the south one-third of the block.

The fertilizers used in the orchard were nitrate of soda, nitrate of potash, and ammonium phosphate. The fertilizers were applied according to the age of the tree, receiving in 1938 as high as 15 pounds of the different nitrogen carriers per tree. The cultural treatments consisted of alfalfa, non-leguminous sod, and cultivation. These cultural and fertilizer treatments were so arranged that each cultural practice received in the different rows which it encompassed, several replications of the different fertilizer treatments. Single rows were not split as to treatment but received the same treatment throughout its length for the sake of simplicity and the avoidance of labor mistakes. Every other row was a check row receiving no fertilizer treatment. Thus, the check trees were greatly in excess of any given treatment compensating to some extent for the variations which might occur due to soil differences, individual tree differences, and other factors which might enter in when dealing with biological material.

The firmness of the fruits was determined with a Magness and Taylor pressure tester similar to the one described in United States Department of Agriculture Circular 350. The same pressure tester was used throughout the 5 years of the experiments. Circumference of the fruit was obtained with a steel tape measuring device developed at Washington State College. Changes in the ground color were de-

[1]The work covered in this report was carried out under the direction of Dr. A. J. Heinicke and was completed while the author was a member of the Department of Pomology, Cornell University, Ithaca, New York.

termined by using a chart similar to the one advocated by Magness, Diehl, and Haller. A Weiss portable refractometer was used to determine the percentage of soluble solids present in the fruit. Soluble solids were determined only for the years 1938 and 1939. Solar radiation data were obtained by use of an Eppley thermoelectric pyrheliometer and a Leeds and Northrup micromax potentiometer. The percentage storage diseases developing was recorded for the successive storage examinations. Previous to 1937 the samples placed in storage were of a composite nature, but during 1937 and 1938 pickings were made from separate trees. Some 231 individual trees were used in 1937, and in 1938, 99 trees were used. Several successive harvests were made from these individual trees.

Results

The experimental work of the years 1934, 1935, and 1936 was of a preliminary nature since the trees were just coming into bearing and the crop was too small to permit any extensive studies. This preliminary work did indicate that the Cortland was highly variable in ripening and for best results in storage should be picked at least twice leaving the fruit to benefit from the higher leaf-fruit ratio. It was evident from even the first year that the major consideration in Cortland storage is the prevention of storage scald. Rasmussen (5) and Christopher (1) found in general that development of scald on the Cortland was related to the time of harvest, finding a marked reduction in scald with increased maturity of the fruit. It is believed, however, that other factors rather than that of maturity alone are involved. Pressure test data obtained at weekly intervals indicate a drop of roughly 1 pound in pressure for each week after the fruit has begun to soften on the tree until the pressure has decreased to approximately 13 to 13½ pounds. Following that, the pressure drops roughly 3 pounds during the next 7- to 10-day interval. Fruit picked at the time when the pressure test is 13 to 13½ pounds pressure, making use of a Magness and Taylor pressure tester fitted with a 7/16-inch plunger, has given the best results taking into account both storage and edible quality. This degree of firmness occurs approximately 10 to 12 days after the peak of the McIntosh harvest. Because this change in firmness of the flesh occurs so abruptly, it is believed that the Cortland apple is one of the few for which the time of harvest may be determined by making use of a pressure tester to determine maturity. This pressure of 13.5 pounds is the average pressure of the fruit when the ground color has begun to take on a slight yellowish tinge or when the ground color is roughly 2.8 according to the color charts published in United States Department of Agriculture Farmers' Bulletin 1406.

Trees to which nitrogen was applied produced fruit which developed much less scald than fruit from check trees. Sodium nitrate and potassium nitrate were much better nitrogen carriers, evidently, than was Ammo-phos as indicated by significantly different yields and a high amount of scald development. Trees from the Ammo-phos plots yielded only one-half that of trees from plots receiving the other nitrogen carriers. In the two years that the soluble solids were determined,

TABLE I—EFFECT OF FERTILIZER TREATMENT ON THE SOLUBLE SOLID CONTENT OF CORTLAND APPLES (1939)

Treatment	Date Harvested	Trees (Number)	Date Determined	Soluble Solids (Per Cent)
$NaNO_3$	Sep. 30	8	Oct. 1	14.61
KNO_3	Sep. 30	12	Oct. 1	14.33
Checks	Sep. 30	22	Oct. 1	13.67
$NaNO_3$	Oct. 3	9	Oct. 4	15.16
KNO_3	Oct. 3	12	Oct. 4	14.93
Checks	Oct. 3	23	Oct. 4	13.87

the nitrated plots had by far the higher soluble solid content than did the non-nitrated or check rows. The comparative increase during a 4-day period in the soluble solid content of the nitrated and the check rows in the 1939 season as is shown in Table I is noteworthy. The nitrated plots showed an increase in the soluble solid content, which was nearly three times that taking place in the check trees for the same period of 4 days. This is probably a partial explanation of the effect of nitrogen in bettering the keeping quality of Cortland. By means of large increments of photosynthate at approximately the time of harvest, an improvement of storage quality is to be expected.

Collison (2) observed with alternately planted McIntosh and Cortland on an unusually uniform soil with trees receiving an equivalent nitrogen application, that the Cortland did not show the fine foliage characteristics of the McIntosh with the Cortland having the appearance of non-nitrogen trees. This same observation has been made in widely separated fruit-growing areas of New York State. These observations and the results of these experiments point to the fact that the Cortland variety may require a much higher application of nitrogen than do many varieties to produce trees with highly efficient leaf surface, which in turn will give yields of fruit of good storage quality.

The growing season of 1937 was cloudy and rainy, while those of 1938 and 1939 were rather dry with comparatively few cloudy days. The fruit of the 1938 and 1939 crops showed much better storage quality than did that of the 1937 crop. Tables II and III, which are typical of much of the data obtained on scald development with fruit exposed to room temperature, shows the effect of maturity, climatic conditions, and nitrogen fertilizer applications. The effect of nitrogenous fertilizers on decreasing the amount of scald is quite apparent, as is also the effect of successive later picking dates. The total solar radiation received up to October 22, 1937, the time of the late harvest for that year, did not begin to approach the amount of solar radiation received by September 20, 1938, the time of the first harvest for that year. The effect of climate on scald development in these two markedly contrasting years lends support to the suggestion of Haller and Harding (3) that fruit grown in seasons of ample rainfall, which would usually mean less sunlight, should not be held in storage as long as that that has been grown with somewhat deficient soil moisture. In 1937 there were probably three factors operating to cause poor storage quality. With the excess soil moisture of

TABLE II—SCALD DEVELOPING ON CORTLAND APPLES EXPOSED AT ROOM TEMPERATURE FROM APRIL 3 TO 7, 1938 (TEMPERATURE RANGE 72 TO 76 DEGREES F, RELATIVE HUMIDITY 25 PER CENT)

	Harvested Sept. 27, 1937				Harvested Oct. 8, 1937				Harvested Oct. 15, 1937				Harvested Oct. 22, 1937			
	Average Scald (Per Cent)				Average Scald (Per Cent)				Average Scald (Per Cent)				Average Scald (Per Cent)			
Hours' exposure	24	48	72	96	24	48	72	96	24	48	72	96	24	48	72	96
$NaNO_3$	64.5	79.7	86.4	89.4	44.2	57.6	66.9	66.9	24.8	47.7	53.2	58.1	13.0	27.8	33.3	35.2
KNO_3	58.6	74.2	79.7	83.8	46.7	71.4	76.9	81.1	35.9	55.8	67.9	73.0	19.4	34.3	48.2	53.7
Checks	69.3	88.0	90.7	91.5	38.8	69.8	78.6	85.0	42.9	64.8	74.4	79.0	34.4	47.0	56.4	63.5
Ammo-phos	50.1	79.1	84.9	89.6	38.4	69.5	77.5	78.3	33.0	46.2	53.3	58.4	12.8	28.3	36.7	45.0
Checks	48.0	74.1	77.2	81.9	30.7	53.0	61.1	62.8	23.0	35.2	43.6	49.3	18.2	27.0	37.3	42.1
Solar radiation from petal drop to harvest date	51,692 gr. cal.				54,045 gr. cal.				55,105 gr. cal.				56,014 gr. cal.			

TABLE III—SCALD DEVELOPING ON CORTLAND APPLES EXPOSED AT ROOM TEMPERATURE FROM MARCH 19 TO 25, 1939 (TEMPERATURE RANGE 72 TO 76 DEGREES F, RELATIVE HUMIDITY 25 PER CENT)

	Harvested Sept. 20, 1938					Harvested Oct. 1, 1938					Harvested Oct. 10, 1938				
	Average Scald (Per Cent)					Average Scald (Per Cent)					Average Scald (Per Cent)				
Hours' exposure	24	48	72	96	120	24	48	72	96	120	24	48	72	96	120
$NaNO_3$	13.9	24.1	24.1	24.1	26.9	18.8	22.9	32.9	32.9	32.9	10.5	18.9	18.9	22.2	22.2
KNO_3	13.9	18.0	18.0	18.0	18.0	13.0	15.7	15.7	18.5	18.5	6.9	15.7	15.7	19.0	19.0
Checks	68.9	73.9	74.8	77.4	80.6	44.7	53.0	55.8	56.4	56.4	29.3	43.4	44.7	51.3	51.3
Ammo-phos	42.8	50.0	54.7	54.7	54.7	28.6	33.3	38.1	38.1	38.1	23.8	28.6	28.6	30.9	30.9
Checks	57.1	64.3	64.3	66.7	66.7	33.3	45.2	47.6	47.6	47.6	16.6	30.9	33.3	38.1	38.1
Solar radiation from petal drop to harvest date	58,192 gr. cal.					61,328 gr. cal.					63,984 gr. cal.				

that year, there is the dilution effect as described by Haller and Harding which makes for a lower concentration of soluble solids. In addition to the dilution effect, there is in all probability the lessened production of photosynthate and the greater use of carbohydrates by other tissues. These three factors would act to cause a comparatively low soluble solid content. The years 1938 and 1939 on the other hand were relatively dry in the Ithaca area with much sunny weather; therefore, light for photosynthesis was less limiting, the dilution factor did not enter in as much to lower the percentage soluble solids, and the use of carbohydrates by rapidly growing tissue was not so great.

It was observed for a number of years that the smaller sized fruits of the Cortland variety were not nearly so susceptible to storage scald as were the larger fruits. To express this observation more definitely, a group of apples harvested October 1, 1938, varying greatly in size and color and from all treatments, was checked for scald development on May 1, 1939. The data obtained are presented in Table IV. These data indicate a direct correlation between size and scald development with the smaller size ranging from 15 to 18 centimeters in circumference showing by far the least scald.

Overmature breakdown is not the problem it was once supposed to be with this variety if the apples are picked within a reasonable time limit. Even on the later picked fruit of the years after the orchard began to bear fairly heavily, overmature breakdown seldom accounted for more than 4 per cent at a maximum of the wastage occurring late in the storage season. Observation and data through these 6 years in which these experiments were conducted show that this storage trouble becomes less important as the trees become older.

It is a common observation that the flesh of the Cortland apple does not oxidize when the cut surface of the fruit is exposed to the air.

TABLE IV—Scald Development as Affected by the Size of the Fruit (Cortland Variety)*

Circumference (Cms)	Fruits Examined (No)	Scald (Per Cent)
15 to 18	44	5.71
18 to 20	81	20.99
20 to 23	238	26.89
23 to 27	132	35.61

*Apples examined were from all treatments, crop of 1938.

Following the technique described by Overholser and Cruess (4), it was shown that the oxidase system of the Cortland was complete. The qualitative test for peroxidase showed that it was strongly present. Organic peroxides while present were liberated only in small amounts. Often over 60 minutes were required before the starch-potassium-iodide test showed any results and even then it was only to a slight extent. The failure to liberate organic peroxide in sufficient amounts accounts for the non-oxidation of the tannin-like compounds or chromogen of the Cortland. After about 2 hours' exposure to the air, the flesh of the variety tends to cork over, preventing to a large extent

further oxidation. If the apple is bruised or the tissue macerated, sufficient organic peroxide is liberated to cause a rapid browning of the flesh. Fully mature fruit also shows some oxidation, whereas the less ripe fruit seldom oxidizes.

The internal appearance of the Cortland throughout the storage season is excellent if picked at the proper stage of maturity. This variety has not been known to show internal breakdown or core browning at the storage temperature of 32 degrees F. The carpellary tissue has been found to be extremely compact when compared to the other tissues of the Cortland apple, hence it is the last tissue to break down.

Discussion

The important consideration in the storage of the Cortland is storage scald. From the results of these experiments, it would seem that any condition or practice which would be effective in increasing the amount of photosynthate available to the fruit as the apples approach maturity would make for an improvement in the storage quality of the variety by the reduction of scald.

The mistake should not be made of considering this variety ripe when it becomes highly colored, but rather, picking should be delayed until the ground color takes on a yellow tinge and the pressure test is from 13 to 13½ pounds.

Since red color development and ability to hang to the tree do not offer much of a problem with this variety in the Northeast, the trees should be more heavily nitrated than most varieties so that the leaves not only stick on the trees longer but also remain in a higher state of efficiency to better provide the high sugar content that seems to make for better storage quality. Spacing the trees so that light is not a limiting factor, the practice of judicious pruning so that shading effects are reduced to a practical minimum, and spot-picking the fruit removing those that are well colored and mature, making a higher leaf fruit ratio for the apples that remain on the tree, are practices which seem to result in improved storage quality.

As the trees become more mature, scald will become less of a factor since with larger trees and heavier crops the size of the individual fruits declines, and there seems to be a direct correlation between the size of the Cortland fruit and the percentage of scald developing.

The relationship of weather during the growing season to storage quality cannot be disregarded. Seasons of ample sunlight and light rainfall resulted in a much better keeping fruit than in seasons in which the weather is predominantly cloudy and rainy. In years in which there is much rain or cloudy weather, Cortland should not be stored as long as in years in which the season is predominantly sunny. Excess soil moisture has a diluting effect on the soluble solid content; cloudy weather, other factors being equal, decreases the amount of photosynthesis taking place; and the use of carbohydrates by other tissues is increased. The net result is lower soluble solid content of the fruit and poor keeping quality.

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Red Color Increase in Fruits After Harvest Following Treatment With Methyl Bromide

By L. L. Claypool, *University of California, Davis, Calif.*

THE red color of apples, peaches and pears reaches its greatest development at the time of harvest and normally does not increase in quantity thereafter (1), although the disappearance of chlorophyll during subsequent ripening processes may cause it to appear greater. Reports have been made by several investigators (2, 3) regarding increasing the amount of red color on these fruits, but the methods have all been related to further exposure to light.

In the course of investigations on gas fumigants for fruits an interesting color effect was noted on peaches. As a result a number of tests have been made to determine the effect of methyl bromide upon the red color development of peaches, nectarines, pears and apples in

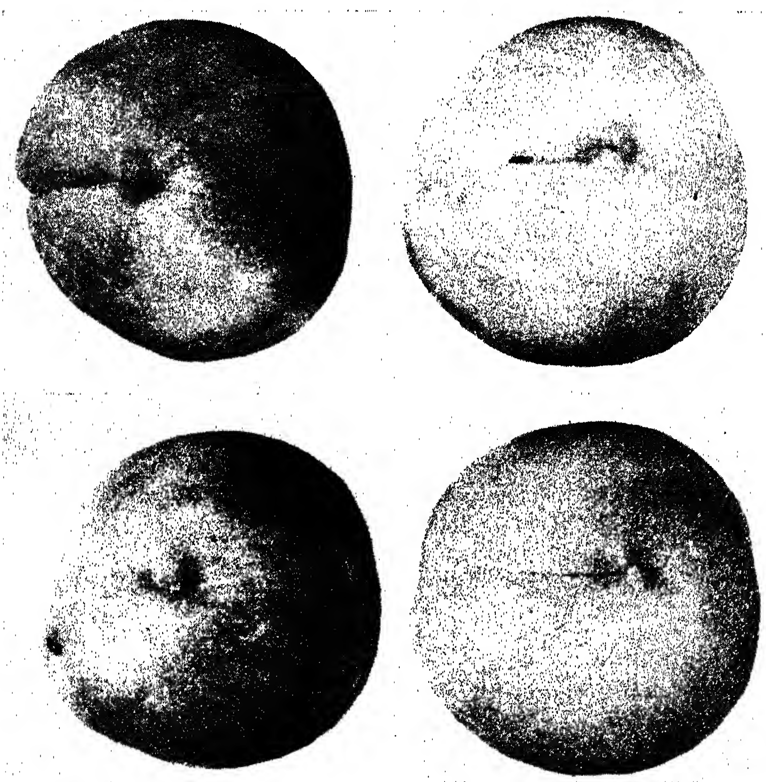

Fig. 1. Levi Cling peaches. Blushed fruits fumigated with methyl bromide, 2 pounds, 2 to 4 hours. Other fruits similar at harvest but without subsequent fumigation.

the dark at a temperature of about 68 degrees F and 85 per cent relative humidity.

Methyl bromide at the rate of 1, 2 and 4 pounds per 1,000 cubic feet for periods of 1, 2 and 4 hours was used in the tests. In all varieties of peaches and nectarines tested the amount of red color was considerably increased after a 2 to 5 day holding period. However, only varieties naturally developing a red blush were used in these tests. The treatments giving greatest red color development were CH_3Br, 2 pounds — 2 hours, 2 pounds — 4 hours, and 4 pounds — 1 hour. Milder dosages had only a slight beneficial effect on color and greater dosages caused injury and failure of the fruit to ripen normally. The Levi cling peach showed the most striking increase in red color of any peach or nectarine. The quality of color was always excellent and seemed to be superior even to the red color already present.

Unfortunately, however, in all of the tests with peaches or nectarines where color was enhanced the flavor of the fruit was definitely injured, thereby eliminating any immediate commercial application of these findings.

In one test with Delicious apples it appeared that an increase in red color occurred. However, additional tests did not confirm this. If the amount of red color on apples can be increased there may be a critical time for treatment. Methyl bromide is rather toxic to apples and 2 pounds for 2 hours is close to the maximum limit without causing injury to flavor and appearance. Bartlett and Comice pears showed no red color development after fumigation.

These results indicate that red color development in peaches and nectarines may continue after harvest in the absence of light. Whether the processes responsible for the continued color development are associated with the formation of precursors to the pigment or changes in the chromogen from colorless to colored forms is not known. Information on this subject might be of value in developing a process that would increase pigmentation without the off flavors resulting from methyl bromide.

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Treatment of Peach Seed as Affecting Germination and Growth of Seedlings in the Greenhouse

By D. H. Scott and J. G. Waugh, *U. S. Horticultural Station, Beltsville, Md.*

In PEACH breeding work at the United States Horticultural Station, Beltsville, Maryland, the seedlings are started in the greenhouse and later transferred to the field. This is done in order to obtain as large a tree as possible the first season and thereby shorten the length of time required to bring the new seedling into bearing.

Two years' results in growing the seedlings in the usual manner in the greenhouse were unsatisfactory, from the standpoint of the germination of the seed as well as the survival of the seedlings in the pots. In an effort to overcome low germination, obtain a good survival of seedlings, and get vigorous plants for potting, certain different methods of handling the seed have been tried, and the results of the trials are reported here.

General Methods and Materials

Three separate experiments were conducted over a 2-year period. The first two trials were concerned mainly with the effect of different media on germination of after-ripened seed. The third included different methods of handling the seed on each of several different media.

In all the trials standard wooden flats were used. The flats were divided into three equal-sized sections, each section being considered as a plot. A different germination medium was placed in each section. The plots were randomized and replicated a number of times, depending on the experiment. Sterilization was accomplished by placing the flats containing the various materials in a large steam-pressure sterilizer. Seeds were after-ripened in a cold-storage room kept at 38 to 40 degrees F.

Procedure and Results

Experiment I, Procedure:—The first trial was made in the spring of 1939, using the germination materials indicated in Table I. Uniformly sized Carolina natural seed was used. The pits were soaked in water 2 days and stratified for 75 days at 38 to 40 degrees F in boxes of sterilized sharp bank sand, which was moistened every 2 to 3 weeks. On May 12 the pits were washed free of sand, and 50 seeds with the pits uncracked were planted in each plot.

Just before the end of the stratification period the germination media (Table I) were prepared, placed in the flats, and sterilized. Four replicated plots per treatment were used. The soil was a composted clay loam used in greenhouse work. The black muck was in a very finely divided state. All combinations of the materials, which were in a 1:1 proportion, were thoroughly mixed in the pile before being placed in the plots. Vitamin B_1 was used in solution in a concentration of 1 part per million, and indolebutyric acid in a concentration of 20 parts per million. In these last treatments the solutions were poured over the plots on the 1st, 4th, 7th, and 10th days after seeding.

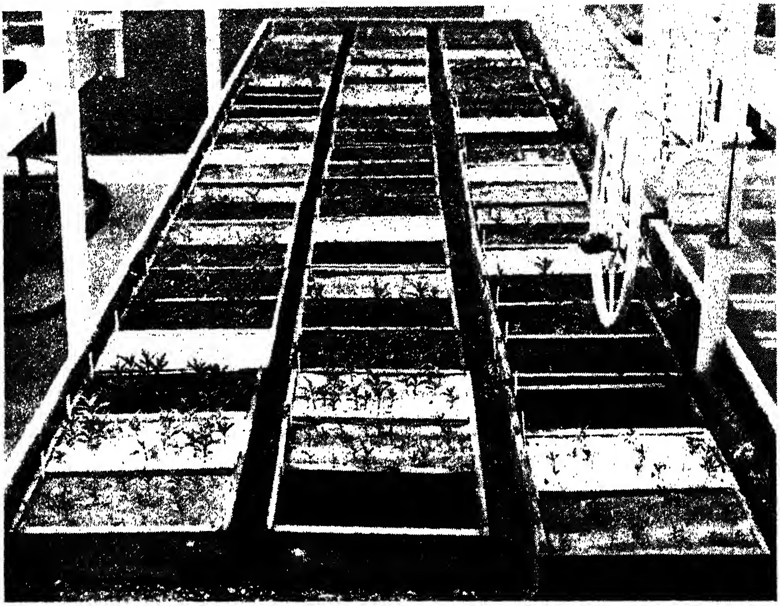

Fig. 1. Plot layout for Experiment I. Germination about half completed.

The first seedlings appeared above ground in some of the media on the 8th day from seeding, and the last seedlings had appeared in all plots in about 3 weeks. At the completion of germination the seedlings were washed out of the plots and 10 seedlings per plot were selected at random and dried for 2 days at 65 degrees C to determine the relative dry weight of the seedlings.

Results:—The condensed results are shown in Table I. Although analysis of variance of the germination data shows slightly significant differences for some of the media, germination on the best plots was still too low to be satisfactory. The wide difference in coefficient of variability of germination in the materials indicates there was some disturbing factor present, possibly disease or inadequate after-ripening of the seeds. Some of the seedlings had a necrotic region on the stem from the ground line down to the branched root system. In many instances the stem was completely girdled. Despite this condition, germination was slightly better for the muck, sand-muck, and muck-peat plots, than for soil, peat, sand-peat, and the indolebutyric acid plots.

There were differences in the velocity of germination as shown by Kotowski's formula (7). Seed in muck and sand-muck germinated more quickly and more uniformly than seed in soil or quartz sand. Where indolebutyric acid at 20 parts per million was applied to the sand plots, the seed germination was definitely inhibited.

The poorest growth was made by seedlings in the peat and sand-peat material. Plants in these media at the end of the 3-week period were short, with small leaves showing a necrotic area at the tip; the apical

TABLE I—EFFECT OF SOME MATERIALS ON PEACH SEED GERMINATION AND SEEDLING GROWTH

Material	Germination				Dry Weight† (Gram)
	Average Number*	Per Cent	Coeff of Variability	Coeff of Velocity**	
Bank sand	23.0	46.0	33.39	8.24	3.48
Quartz sand	24.2	48.4	28.63	7.20	3.63
Soil (composted)	19.7	39.4	32.08	7.84	4.23
Muck	26.2	52.4	15.26	9.17	4.73
Peat	20.0	40.0	21.80	—	1.90
Bank sand—soil	24.5	49.0	17.30	8.05	4.03
Bank sand—muck	28.5	57.0	19.50	8.94	4.18
Bank sand—peat	20.5	41.0	22.92	—	2.25
Soil—muck	22.0	44.0	22.72	8.09	4.53
Soil—peat	24.5	49.0	25.46	—	4.65
Muck—peat	28.0	56.0	17.50	—	4.22
Sand—soil—muck—peat (1:1:1:1)	26.0	52.0	18.07	—	4.15
Bank sand—vitamin B_1	19.5	39.0	10.25	—	3.23
Bank sand—indolebutyric acid	18.7	37.4	16.90	5.72	2.53
Quartz sand—vitamin B_1	18.5	37.0	29.62	—	4.03
Quartz sand—indolebutyric acid	15.0	30.0	47.13	5.75	2.73
Difference for significance 19:1	7.1	—	—	0.61	0.79
99:1	10.6	—	—	0.91	1.18

*50 seeds per plot planted in four replicated plots.
**Calculated by Kotowski's formula.
†10 seedlings per plot.

point of the stem was dead; and the cortex of the stem portion below ground was apparently girdled. Dorsey (3) apparently found peat to be satisfactory as an after-ripening medium, but does not state whether the seedlings were grown in the material. When peat was used with soil or muck, however, seedling growth appeared normal. Plants growing in muck, muck-soil, and soil-peat were thrifty and vigorous. These observations are reflected in the dry weights of the plants. The pH of the peat was 4.24 to 4.28 and the sand-peat 4.24 to 4.60; whereas the pH of the muck ranged from 5.82 to 5.92, muck-soil 6.27 to 6.48, and soil-peat 5.95 to 6.23. The root systems of plants growing in sand-muck and muck appeared to be larger and more finely branched than of those growing in the other materials. Vitamin B_1 did not seem to have any effect on root development. Indolebutyric acid produced a marked effect on the root system — three or four thick, heavy main roots were formed which showed only a few secondary rootlets in contrast to the finely branched roots produced in the muck.

Experiment II, Procedure:—Because of their performance in the previous experiment, seven materials (Table II) were chosen for further study in the fall of 1939. These were replicated six times. The procedure was the same as in the first test, except that 48 seeds per plot, instead of 50, of Carolina natural peach were used. Moreover, the pits were disinfected with 2 per cent chlorinated lime and stratified intact for after-ripening in the plots in which they were germinated rather than in a different box, as in Experiment I. This was done in order to reduce danger of disease contaminating the after-ripened pits. At the completion of germination, measurements were made of the linear stem length of the 10 seedlings used for dry weight determination.

Results:—On the whole, germination in this trial for some of the

TABLE II—Germination of Peach Seed and Early Growth of Seedlings as Affected by Various Media

Media	Germination			Dry Weight† (Gm)	Stem Length‡ (Cm)
	Average Number*	Per Cent	Coeff of Velocity**		
Bank sand	29.6	61.7	16.29	4.23	20.9
Quartz sand	15.6	32.5	13.23	3.93	19.2
Soil	29.1	60.6	16.35	4.08	22.2
Muck	20.1	41.9	23.33	5.18	25.4
Muck—soil	21.6	45.0	22.32	5.10	27.2
Sand—muck	15.8	32.9	19.00	4.76	24.1
Sand—soil	30.0	62.5	18.90	4.73	25.0
Differences for significance 19:1	8.2	—	4.61	0.45	1.75
99:1	12.3	—	6.91	0.68	2.63

*48 seeds per plot planted in six replicated plots.
**Calculated by Kotowski's formula.
†10 plants per plot.
‡Average of 10 plants per plot.

media was somewhat superior to the previous test, as shown by Table II. There were distinct differences due to the various materials used. Bank sand, sand-soil, and soil were superior to the others in percentage of germination, but there was still considerable variation in the plots.

Seedling emergence again showed the rate of seed germination to be most rapid in the muck and muck-soil and slowest in fine quartz sand.

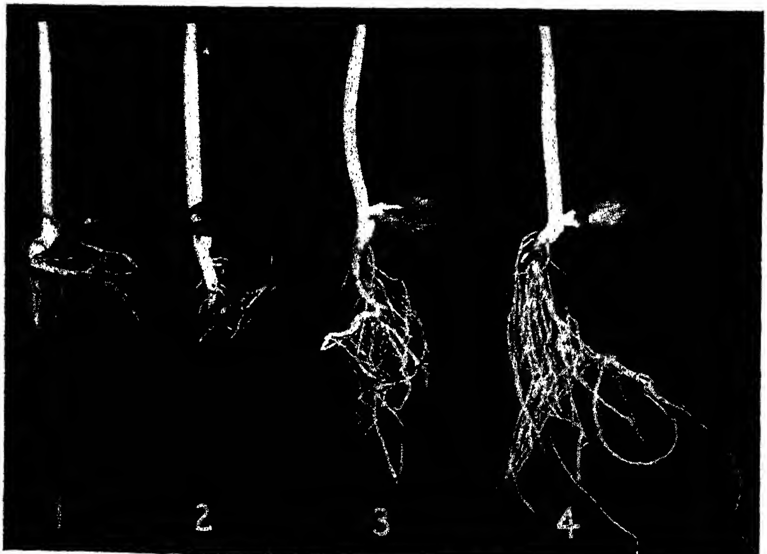

Fig. 2. Effect of germination media on the root system when the plants are removed for transplanting: (1) Composted soil; (2) sand-soil; (3) sand-muck; (4) muck.

The largest plants, as shown by dry weight and linear stem length, were grown in the muck and muck-soil plots. Leaves on plants in muck and sand-muck were larger and darker than leaves of plants from other plots. There were practically no diseased seedlings in any of the materials.

In removing the plants from the plots it was noticed that roots of seedlings grown in soil and sand-soil were very brittle. On the other hand, the root systems of plants in muck and sand-muck were not brittle and were easily removed intact from the media (Fig. 2).

Experiment III, Procedure:—The influence of some germination materials on methods of handling the seed was studied in the summer of 1940. Three materials: bank sand, 1:1 mix of bank sand and muck, and fine quartz sand were selected because of differences previously obtained when seeds were germinated in them.

Seeds were saved at Beltsville in the fall of 1939 from trees of Elberta and Gold Drop. Gardner and Marth (4) have shown the former to be a weak germinator and the latter a strong one under field conditions. Previous to planting, the seeds were held at room temperature in air-dried condition.

The pits were soaked in water for 3 days prior to stratification, after which they were divided into two lots; the pits in one lot were left uncracked; those in the other lot were cracked and the seed removed. The pits or seeds were after-ripened in the plots in which they were to germinate, as in Experiment II.

Two periods of after-ripening at 40 degrees F were used, one at 65 days and the other at 115 days. Seeds in the 65-day lot were placed in the 40 degrees temperature 50 days later than the 115-day group, so that all seeds could be removed from storage at one time and be subjected to the same germination conditions in the greenhouse. Relative humidity was 85 to 95 per cent in the chamber, but it was necessary to water the flats about every 3 weeks to maintain uniform moisture conditions in the media. A small fan in the room was kept going constantly.

The treatments were so planned that the factors were used in all possible combinations with each other as in a factorial design. This resulted in 24 combinations, which were replicated three times to give a total of 72 plots, with 40 seeds used in each plot. The treatments were randomized within the blocks so that the data could be analyzed by use of analysis of variance.

The flats used were provided with excellent drainage by enlarging the holes in the bottom and placing 16-mesh copper wire screen over the openings. The media were placed in the plots at random and the flats sterilized as before.

Results:—In this trial there was no difference in germination in the three kinds of media (Table III); neither was there any difference in germination between varieties. This indicates that a variety which sometimes shows low germination in the field may germinate well under greenhouse conditions. Germination was good in all lots after-ripened for 115 days, but was definitely lower in some of the 65-day lots. Both varieties in the 65-day lot and Gold Drop at 115 days had

TABLE III—EFFECT OF DIFFERENT SEED TREATMENTS AND THREE KINDS OF MEDIA ON PEACH SEED GERMINATION AND EARLY GROWTH OF THE SEEDLINGS

Seed Treatment			Seed Germination		Size of Seedlings	
Media	Pit Treatment	Days After-Ripened	Per Cent*	Coeff of Velocity	Dry Weight** (Gm)	Stem Length† (Cm)
		Gold Drop				
Bank sand	Cracked	115	89.2	12.10	4.33	18.9
Quartz sand	Cracked	115	93.2	11.84	4.07	17.8
Sand—muck	Cracked	115	80.7	12.34	4.30	19.3
Bank sand	Cracked	65	88.2	6.64	3.43	9.8
Quartz sand	Cracked	65	93.2	7.25	4.20	12.3
Sand—muck	Cracked	65	89.2	7.91	3.40	14.1
Bank sand	Intact	115	87.5	8.45	3.53	11.3
Quartz sand	Intact	115	78.2	7.45	3.63	10.3
Sand—muck	Intact	115	70.7	11.31	4.23	18.6
Bank sand	Intact	65	52.5	5.56	3.20	6.7
Quartz sand	Intact	65	60.7	5.52	3.10	4.8
Sand—muck	Intact	65	70.7	6.85	3.47	11.6
		Elberta				
Bank sand	Cracked	115	85.7	10.93	4.87	17.4
Quartz sand	Cracked	115	87.5	11.63	5.33	19.6
Sand—muck	Cracked	115	84.2	12.07	5.23	21.7
Bank sand	Cracked	65	79.2	7.20	4.43	11.7
Quartz sand	Cracked	65	87.5	7.40	3.96	11.2
Sand—muck	Cracked	65	85.0	7.95	4.70	17.1
Bank sand	Intact	115	89.2	8.27	4.43	15.3
Quartz sand	Intact	115	93.2	9.11	4.90	15.7
Sand—muck	Intact	115	85.0	10.56	5.27	21.4
Bank sand	Intact	65	65.0	6.75	4.23	10.4
Quartz sand	Intact	65	60.7	6.90	4.47	9.6
Sand—muck	Intact	65	64.2	7.29	4.33	14.2

*40 seeds planted per plot with three replicated plots.
**Total of 10 plants per plot.
†Average of 10 plants per plot.

more seed germinated from the cracked pits than from pits left intact. Elberta seed did not show any difference in germination between cracked and uncracked pits in the 115-day lot.

TABLE IV—ANALYSIS OF VARIANCE OF PEACH SEED GERMINATION AND SEEDLING GROWTH FOR EXPERIMENT III

Source	D. F.	Germination Counts (Mean Squares)	Dry Weights (Mean Squares)	Coefficient of Velocity (Mean Squares)
Varieties	1	2.72	15.8673**	1.011
Media	2	10.06	0.5706*	12.119**
Pit condition	1	544.50**	1.5023**	56.552**
After-ripening time	1	329.39**	6.4800**	229.587**
Variety ×media	2	0.39	0.0438	1.238
Variety ×pit	1	76.06*	0.3471	2.687*
Variety ×time	1	29.39	0.0450	2.750*
Media ×pit	2	8.00	0.1938	2.392
Media ×time	2	47.73	0.1616	1.166
Pit ×time	1	346.72**	0.0800	13.253**
Variety ×time ×pit	1	2.72	0.0672	——
Variety ×time ×media	2	16.89	0.4200	——
Time ×pit ×media	2	8.72	0.1067	——
Variety ×media ×pit	2	6.72	0.3572	——
Block	2	4.06	0.0043	0.785
Error	48	15.69	0.1751	0.668†
Total	71			

*Significant at 5 per cent level.
**Significant at 1 per cent level.
†D. F. =55.

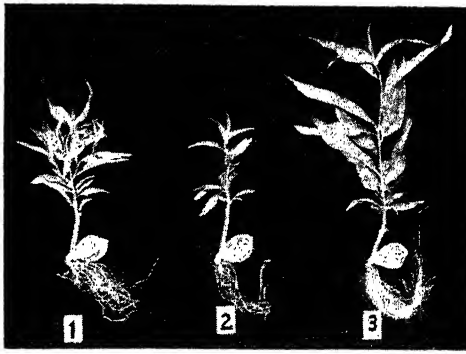

FIG. 3. Elberta seedlings about 3 weeks old. All were after-ripened 65 days with pits intact: (1) Grown in bank sand; (2) quartz sand; (3) sand-muck.

The coefficients of germination velocity for the various treatments show that seeds in sand-muck appear above ground earlier and more uniformly than in either bank or quartz sand. This has been consistent throughout all the work. There was also earlier seedling emergence from lots with cracked pits than from those planted with intact endocarp. The most striking difference, however, was that seedlings after-ripened for 65 days were much slower to emerge than those for 115 days; likewise, in the 65-day lot seedling emergence was much slower for uncracked pits than for the cracked ones. Germination for the 65-day lot was more rapid in the sand-muck plots than in either of the two sands.

Seedlings growing in the sand-muck were somewhat larger than those growing in bank sand or fine sand. Root systems were very good throughout, but were a little superior in the sand-muck material. Statistical analysis of the data indicates a wide difference in final weight of plants, depending on the variety. This is probably due to the fact that Gold Drop seedlings from seed with the pits intact were badly diseased in all plots except the sand-muck, where diseased seedlings were noticeably absent. There were no diseased seedlings except those associated with Gold Drop. The presence of disease in the seedlings from uncracked Gold Drop pits also explains the difference in size of plants under the two methods of handling the pits. The plants of both varieties in the 65-day lots, however, were much smaller than those in the 115-day group, and many of the seedlings in the former group showed the characteristic curled leaves and dwarfing that develop from lack of sufficient after-ripening.

Discussion and Conclusions

The results of this study indicate that the ordinary types of media used for stratification and germination of peach seeds, when provided with very good drainage, are not as important as certain other factors. Excellent drainage in the flats in Experiment III seems to have overcome the germination differences noted in the previous trials with these media. Although drainage was good in the other experiments, too much moisture may have been present in the flats for short periods after the seeds were moistened during after-ripening. The oxygen supply of the seeds would be reduced during this interval and consequently a longer period would be required to complete after-ripening.

Methods of handling the pits are apparently of greater importance from the germination standpoint than different types of media. There

seems to be less danger of the seedlings being diseased if the pits are removed from the seeds prior to after-ripening. Once the seeds are after-ripened they seem to be very susceptible to disease. Contamination is likely to occur if the seeds must be disturbed and transferred from the after-ripening medium to the germination material. Planting the seeds and stratifying them in the flats in which they are to be germinated probably reduces the number of diseased plants and increases the percentage of germination.

When the endocarps were removed, the 65-day after-ripening period yielded as high a germination as the 115-day period, but seedling emergence was slower in the former, and many of the plants showed the dwarfed condition associated with lack of sufficient after-ripening. Haut (6) has shown that a 75-day after-ripening period at 38 degrees F is sufficient for peach seeds.

It is evident from the data in Table III that with the pit intact the seeds in the 65-day after-ripened lot did not germinate as well as those given the 115-day treatment. Crocker (1), Crocker and Barton (2), Dorsey (3), and Haut (6) all show that removing the endocarp increases the percentage of germination of peach seeds. This is borne out in the present work except in the case of Elberta seed after-ripened 115 days. Removal of the endocarp in this group did not increase germination above that obtained where the pits were left intact.

Seedling emergence, as measured by coefficient of velocity of seed germination, may be associated with the amount of after-ripening a seed receives as indicated in Table III. Slow seedling emergence may mean lack of sufficient after-ripening. If such is the case, the data would indicate that seeds stratified in the sand-muck had received more suitable conditions during the after-ripening period than had seeds in either of the two sands.

The retarded growth of seedlings where 20 parts per million of indolebutyric acid was applied is probably due to the high concentration used. Other workers (5, 8) have reported that the higher concentrations of certain growth promoting substances retard growth.

Size and vigor of seedlings have been consistently superior where muck has been incorporated with sand, as contrasted with seedlings in pure sand. For this reason a sand-muck mixture is used for after-ripening and germination of seeds in breeding work at the present time.

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Wind Damage to Apple Trees on Selected Rootstocks, Kearneysville, West Virginia, July 28, 1940[1]

By R. H. Sudds, *West Virginia University, Morgantown, W. Va.*, and P. C. Marth, *U. S. Horticultural Station, Beltsville, Md.*

AT THE University Experiment Farm, Kearneysville, West Virginia, there are several plantings of apple trees on selected rootstocks, all but one of which are conducted in cooperation between the United States Department of Agriculture and West Virginia University. Since 1937 several reports by Yerkes and Sudds, chiefly concerning the growth responses of these trees, have appeared in these Proceedings. In this present instance, the subject is the degree to which certain of these apple trees on known rootstocks either resisted or else failed to withstand winds of high velocity.

On July 28, a severe electrical storm accompanied by high winds of an unknown velocity struck Kearneysville. Approximately an inch of rain fell during the storm; most of this followed the winds. The precipitation records showed that the rainfall for May, June, and July was about one-half inch less than the 40-year average. While no samples were taken before the storm, the soil-moisture content was unquestionably much below the field capacity. When apple trees at Kearneysville were blown over, a breakage of roots close to the main axis, on the windward side of the tree, was involved in every case. In no instances were large circular discs of soil and roots raised and tilted as, for example, in the New England hurricane of September, 1938, nor were large roots pulled out of the soil.

The soil in which the trees were growing is of the Hagerstown series; the texture varied from a silt loam to a silty clay loam. A few small spots of the clay loam were present near eroded limestone outcrops.

Procedure in Recording Wind Damage

Since the writers were unable to visit the orchard immediately after the storm and as it was necessary to repair the damage promptly, the work of classifying and recording the types of injury devolved on Mr. Edwin Gould, associate entomologist in charge, to whom the authors express their appreciation.

Two principal classes of injury have been made in reclassifying the results of the storm. The first included those trees which were broken off or blown over with or without attendant root injury, and the second comprised the total number of individuals of each variety — rootstock combination which were damaged in any way. This total included those individuals in the first group plus those with severe damage to the framework.

All three blocks of trees to which reference is made in this report were treated in exactly the same manner in making the classification of the visible wind injury.

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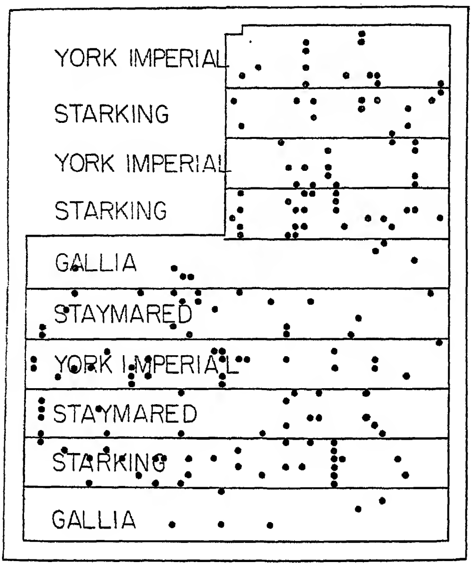

FIG. 1. Block A showing distribution of wind-injured trees, indicated by black dots. Uninjured trees are not shown.

INJURY IN BLOCK A

The layout of this 2644-tree orchard consisting of the Gallia Beauty, Starking, Staymared, and York Imperial varieties of apples on various known rootstocks has been described previously (3, 4). That the wind struck the whole area of this 27-acre block of trees is attested by Fig. 1. Data concerning the Gallia Beauty trees are omitted, as only 13 trees of that variety were visibly injured in a total of 496.

Tables I and II include data on 1729 trees consisting of 595 Starking, 554 Staymared, and 581 York Imperial, both on clonal and on seedling rootstocks. Of these varieties on all rootstocks, 155 trees, or 8.9 per cent, were injured by the wind. Sixty-eight, or 11.4 per cent of the Starking trees were damaged, as were 38, or 6.8 per cent of the Staymared, and 49, or 8.4 per cent of the York Imperial.

Each of the three varieties showed more injury on the clonal rootstocks as a group (Table I) than on the seedlings (Table II). The figures for both classes of injury for the Starking were 15.5 per cent damaged on clonal rootstocks and 5.9 per cent on seedlings; corresponding values for the Staymared were 8.8 and 3.7 per cent, and for the York Imperial they were 9.5 and 6.6 per cent. Totaling the three varieties, 11.3 per cent of those on clonal rootstocks and 5.5 per cent of those on the seedlings were injured.

The proportions of damaged trees were much higher than the average for each of the three varieties on the clonal rootstocks 316 and 317. On Northern Spy variety roots, Staymared and York Imperial were severely damaged, but Starking/Northern Spy was much less injured. Trees on Malling XIII and Malling XV showed the least injury of any on clonal stocks. Compared with the trees on 316 and 317, those on 313, 323, and 329 showed a relatively small amount of injury. York Imperial trees on Malling I, as they grow at Kearneysville, are full dwarfs with all of their well-known shortcomings, which do not appear to merit further consideration for planting in commercial orchards of this area. With Gallia Beauty/Malling I, 2 trees out of 15 were blown over.

With the seedling rootstocks, Wealthy seedlings worked to the

TABLE I—BLOCK-A THREE STANDARD APPLE VARIETIES ON SELECTED ROOTSTOCKS TREES IN EIGHTH GROWING SEASON (CLONAL ROOTSTOCKS ONLY)

Rootstock	Number Blown Over or Broken Off			Total Number Damaged			Total Number on Stock			Per Cent Damaged
	Skg.*	Srd.	York	Skg.	Srd.	York	Skg.	Srd.	York	All Varieties
Malling I........	1	1	12	1	1	12	24	19	22	21.5
316.............	15	9	6	30	11	9	96	90	97	17.7
317.............	3	3	3	5	4	3	24	24	25	16.4
Northern Spy....	1	3	5	2	4	5	24	24	24	15.3
329.............	2	2	1	11	7	3	93	94	98	7.4
323.............	1	2	0	2	2	1	22	24	23	7.2
313.............	2	1	0	2	1	0	19	23	23	4.6
Malling XV.....	0	0	0	0	0	1	24	22	24	1.4
Malling XIII....	0	0	0	0	0	0	15	20	20	0.0
Totals........	25	21	27	53	30	34	341	340	356	11.3

*Skg.—Starking, Srd.—Staymared.

three varieties (Table II) showed no injury, although with Gallia Beauty (the data for which are not given) 2 trees out of 22 were blown over. Northern Spy seedlings budded to Staymared and to York Imperial withstood the wind very poorly but did very well with Starking; this performance was similar to that observed with the clonal rootstock Northern Spy variety. On the McIntosh seedlings, heavy damage resulted to Starking, but when budded to Staymared or to York Imperial, no injury was observed. Tolman seedlings under Starking tops suffered to the extent of one-fifth of their number; however, this test was not entirely comparable, as both outside rows were on Tolman and the full force of the blast struck the full exposed length of one of the two rows on this rootstock.

Grimes Golden seedlings worked to York Imperial, and Winesap seedlings budded to Starking suffered considerably more than average,

TABLE II—BLOCK-A THREE STANDARD APPLE VARIETIES ON SELECTED ROOTSTOCKS TREES IN EIGHTH GROWING SEASON (SEEDLING ROOTSTOCKS ONLY)

Rootstock	Number Blown Over or Broken Off			Total Number Damaged			Total Number on Stock			Per Cent Damaged
	Skg.*	Srd.	York	Skg.	Srd.	York	Skg.	Srd.	York	All Varieties
Northern Spy....	1	1	3	1	4	3	24	22	24	11.4
McIntosh.......	4	0	0	5	0	0	23	12	12	10.6
Tolman.........	2	0	1	4	0	2	20	22	22	9.4
Grimes..........	0	0	6	0	0	6	22	19	25	9.1
Fameuse........	1	1	1	1	1	1	21	8	14	7.0
Rome...........	0	1	0	1	2	0	24	19	25	4.4
Delicious.......	0	0	0	1	1	0	24	21	15	3.3
Winesap.........	2	0	0	2	0	0	24	23	15	3.2
Jonathan........	0	0	2	0	0	2	24	21	24	2.9
French Crab.....	0	0	1	0	0	1	24	24	25	1.4
Wealthy.........	0	0	0	0	0	0	24	23	24	0.0
Totals........	10	3	14	15	8	15	254	214	225	5.5

*Skg.—Starking, Srd.—Staymared.

but with the other two varieties in each case, no damage resulted. French crab with Starking and with Staymared tops showed no injury, while with York Imperial the percentage was lower than average. With Gallia Beauty, French crab seedlings underwent no loss. Rome Beauty seedlings with Staymared exhibited considerable injury, but with Starking their record was good, and with York Imperial none of the trees was affected visibly.

Considering the factor of wind resistance only, seedlings of Wealthy, Jonathan, Winesap, French crab, Delicious, and Rome Beauty were acceptable rootstocks for all four varieties.

In addition to the injury listed in Tables I and II, there were several trees here and there through Block A, which leaned considerably to leeward after the storm. These trees were not blown over and yet they were very considerably out of their normal vertical plumb. No appreciable signs of serious weakness or of looseness in the soil were detected in any of them when efforts were made by hand to push them over the rest of the distance. Probably some injury had been done to the root systems. The combinations represented in these "leaners" were as follows: Starking / 329, six trees; / 316, six trees; / Grimes Golden seedlings, six trees. Staymared/Jonathan seedlings, two trees; / 316, six trees; York Imperial / 316, six trees. Gallia/Northern Spy variety, 12 trees; / 316, one tree; / Grimes Golden seedlings, six trees; / Malling I, four trees. None of these are included in the data presented in the tables which should be consulted in order to obtain some idea of the relative importance of these figures.

Before the data of Block A were analyzed, the suggestion was advanced that the trees with the larger tops, because of the larger surface exposed to the wind, were more likely to be injured than the trees with smaller areas of tops. A study of these factors shows that the mere size of the top had no particularly consistent influence on the resulting damage to the trees of any combination represented in the block. Frequently, all four varieties on any specific rootstock, regardless of tree size, either withstood the wind well or, in other combinations, all scion varieties incurred more or less injury on a particular stock.

It is not clear why the Gallia Beauty trees escaped with damage to only 13 trees out of 496 or 2.6 per cent. While the Gallia Beauty trees averaged smaller than those of any of the other three varieties, the largest-sized individuals, those on the clonal rootstocks 316, 317, and 323, were not much smaller than Starking, Staymared or York Imperial on the same rootstocks. In those latter instances severe damage resulted. Most of the Gallia Beauty trees were bearing a very heavy load of fruit which had sized well when the storm struck; of the 3 other varieties, only Staymared had as much as half a crop. It is known that broken limbs or split crotches are relatively rare with Rome Beauty, and evidently this is also true for Gallia Beauty.

Injury in Block B

Block B consists of 124 trees of six varieties, York Imperial, Gallia Beauty, Jonathan, Staymared, Golden Delicious, and Starking, all on

TABLE III—BLOCK-B SIX STANDARD APPLE VARIETIES ON MALLING II ROOTSTOCKS (TREES IN EIGHTH GROWING SEASON)

Variety	Total Number of Trees		
	On Stock	Blown Over or Broken Off	Damaged
York Imperial	21	1	1
Gallia	19	0	0
Jonathan	21	0	0
Staymared	21	2	2
Golden Delicious	21	1	1
Starking	21	2	2
Totals	124	6	6

Malling II. The experimental layout has been previously described (2, 3). Although the rootstock is said to be markedly "one-sided" as regards the character of its root system, there was no evidence that these were not well anchored. Only six of the trees (Table III) were blown over, including one that was broken off in the process. The site was exposed to the wind fully as much as that of Block A; the two groups of trees are about 100 yards apart. Only 4.8 per cent of the trees were injured visibly, and none of the trees was left leaning to leeward. Only two of the clonal rootstocks and only three of the seedlings in Block A fared appreciably better. With the one tree in Block B, Starking/Malling II, which broke off completely, the fracture was in rootstock tissue, several inches below the probably zone of union.

INJURY IN BLOCK C

These 124 trees, chiefly of Stayman Winesap and Red Rome/Malling XIII and of Starking and Red Rome/Malling I, comprise the only rootstock planting at Kearneysville which is not conducted in cooperation between the United States Department of Agriculture and West Virginia University. The layout of the Red Rome trees on both rootstocks has been given in a previous report (1). The Stayman Winesap and Starking trees were referred to at that time merely as "guard rows" without naming the variety — rootstock combinations; likewise, the growth and yield data for those trees were not given. Fig. 2. presents the distribution of the wind

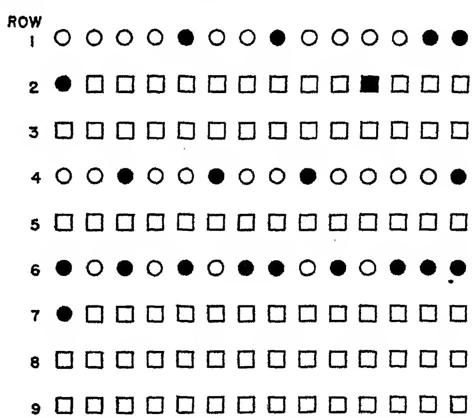

FIG. 2. Block C showing distribution of wind-injured trees, indicated by blacked-in figures. Circles are trees on Malling I rootstocks; squares are trees on Malling XIII rootstocks. Scion varieties: row 1, Stayman Winesap; rows 5 and 9, Starking; all other rows Red Rome.

TABLE IV—Block-C Three Standard Apple Varieties on Malling Rootstocks (Trees in Ninth Growing Season)

Varieties	Stock	Total Number of Trees		
		On Stock	Blown Over or Broken Off	Damaged
Stayman	I	13	3	4
Starking	XIII	28	0	0
Red Rome	XIII	54	1	1
Red Rome	I	29	15	15
Totals		124	19	20

damage, while Table IV gives the injury data for Block C.

Table IV demonstrates clearly the fact that a remarkable difference may be expected in the performance of trees of nearly identical size and of the same scion variety when worked on two different clonal rootstocks. In the case of Red Rome/Malling XIII, one tree was blown down out of a total of 54 of that combination. In contrast, with Red Rome/Malling I, out of a total of 29 trees, 13 were blown over and 2 were broken off in rootstock tissue for a loss of 15 trees, more than 50 per cent of the total number. There had been previous indications (1) that these trees would not stand unsupported. In view of the injury with Gallia/Malling I in Block A, where two of the 15 trees of this combination were blown over—the still more disastrous performance of Red Rome/Malling I in the adjoining Block C is especially interesting. With Stayman/Malling I, two trees were blown over and two split badly, out of a total of 13 trees. The 28 trees of Starking/Malling XIII showed no visible injury of any type.

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Soils and Soil Treatments Affect the Morphology of French Crab Roots[1]

By George A. Filinger, *Kansas Agricultural Experiment Station, Manhattan, Kans.*

A STUDY of French Crab seedlings was recently initiated at the Kansas Agricultural Experiment Station to segregate if possible more desirable apple rootstocks than are now available from this source. Vigor is one of the characteristics being observed. This paper presents some results obtained from a study of the effects of different soil treatments on the morphology of French Crab seedling roots. The study was made to determine how much soil environment might influence root morphology and anatomy as preliminary to a study of the stionic effects of selected French Crab rootstocks. Beakbane and Thompson (1) recently reported that the internal anatomy of apple rootstocks may be an index of their influence on the vigor of cions.

Materials and Method

Twenty-four French Crab seedlings selected for uniformity were divided into six groups of four each. The trees were planted in wooden boxes 18 inches square and 24 inches deep, placing two trees into each box. The soils and treatments varied as follows:

Group 1:—The trees were planted in soil which was obtained from the surface 12 inches of the station orchard. It is a Geary silt loam type of soil. No special treatment was given the soil. The trees were watered as needed for normal tree growth.

Group 2:—The same type of soil was used as in group 1, but about 4 ounces of ammonium phosphate was added to the soil in each box. The trees were watered as necessary.

Group 3:—The trees were planted in the same type of soil as group 1 but were watered only when they showed signs of wilting and then only a small amount of water was added. The boxes were covered to exclude rain water from the boxes but during heavy rains in the early summer some water soaked into the boxes from the sides.

Group 4:—The same type of soil was used as in group 1. The boxes were set into a shallow pan of water in such a way that the lowest inch of soil in each box was continually saturated with water. The water level was kept constant by an automatic water supply.

Group 5:—Trees were planted in a rich, composted soil very high in organic matter and were watered as needed for normal growth.

Group 6:—The trees in this group were planted in a mixture of three parts of sand and gravel and one part of clay. The soil thus prepared was very low in organic matter.

All the trees were planted May 2, 1940, and the boxes (except group 4) were plunged into soil leaving about 3 inches of each box above the level of the ground. The stems were all pruned to a single whip about 8 inches long and only fibrous laterals were left on the main

[1]Contribution No. 172, Department of Horticulture.

TABLE I—EFFECTS OF SOIL TREATMENT ON WEIGHT AND SIZE OF FRENCH CRAB SEEDLINGS

Group	Soil	Average Weight Entire Trees (Grams)	Average Weight Roots (Grams)	Average Caliper at Soil Line (Inch)
1	Orchard	131	61	15/32
2	Orchard + ammonium phosphate	126	62	15/32
3	Orchard, deficient water	83	37	12/32
4	Orchard + constant water at base	156	58	18/32
5	High organic content	117	51	17/32
6	Gravel, low organic content	141	57	17/32

roots. The over-all length of the trees was about 18 inches and each tree weighed about 45 grams when planted.

All the trees were washed out of the soil on October 17, 1940. The sides of the boxes were removed to facilitate washing. The trees were photographed and their entire weights recorded. The roots were then cut off at the "soil line", weighed and measured with calipers. Sample lateral roots from each plant were preserved for anatomical studies.

FIG. 1. Effects of fertilizer on French Crab seedling roots. A, grown in orchard soil; B, grown in orchard soil plus ammonium phosphate.

RESULTS

Data on weights and measurements are presented in Table I.

The average weights of the trees varied from 83 grams for group 3 in dry soil to 156 grams for group 4 with the water at the base of each box. The average weights of the roots varied from 37 grams for the group 3 to 62 grams for group 2 in soil treated with ammonium phosphate. The caliper varied from 12/32 for group 3 to 18/32 for group 4.

Some striking differences were noted in the appearance or gross morphology of the trees and their roots in the various groups as illustrated in Figs. 1, 2, and 3. The trees in group 1 grew well and the roots showed a well balanced distribution of large, me-

dium, and small roots as shown in Fig. 1A. Trees in group 2 grew well but developed many fibrous roots (Fig. 1B). Root systems in group 3 were meager with only a few large roots and a small amount of fibrous roots (Fig. 2B). Trees in group 4 grew vigorously. The upper portion of the root systems closely resembled group 1 but the roots which developed near the water soaked soil at the bottom of the boxes were fibrous and spread out somewhat horizontally. The matted fibrous roots were difficult to wash out of the wet soil (Fig. 2A). Trees in group 5 grew well and developed many fibrous roots that were difficult to separate from the organic matter in the soil (Fig. 3B). Roots on trees in group 6 somewhat resembled group 1 but had fewer fibrous roots. Medium sized roots were abundant and long (Fig. 3A).

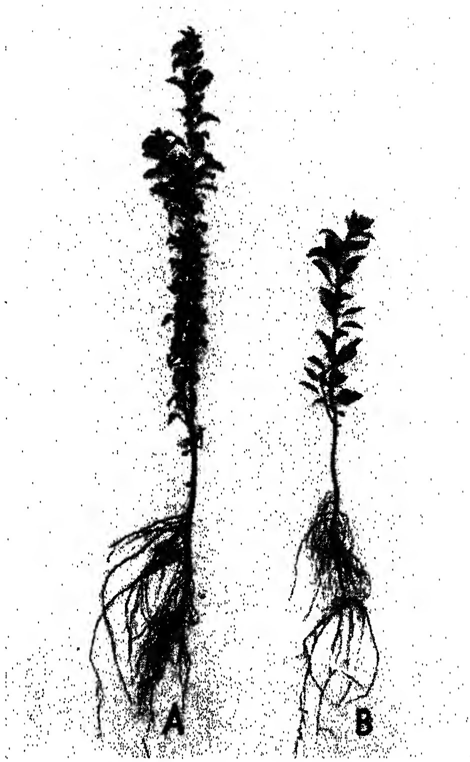

FIG. 2. Effects of moisture on French Crab seedling roots. A, grown in soil with abundant water; B, grown in soil deficient in water.

Microscopic slides were prepared of cross sections of small, medium, and large roots in each group. Small roots measured 0.5 to 0.75 millimeters, medium 1.25 to 1.5 millimeters and large 4 to 5.5 millimeters in diameter. The prepared slides were studied directly under the microscope and portions of typical sections were projected and photographed. Figs. 4, 5, and 6 are photographs of sections of large roots from each group. A study of the sections and of photographs reveals these comparisons: The vessels in roots in group 1, grown in orchard soil, are somewhat more numerous but smaller than those in roots of group 2 where commercial fertilizer was added to the soil. The medullary rays are more abundant and wider in roots of group 2 than group 1. The ratio of phloem to xylem is about the same in the two groups (Fig. 4A and B).

The vessels of roots in group 4 with abundant water are smaller and more numerous than those in group 3 where water was deficient. The ratio of ray tissue to other tissue is greater in group 3 than in group 4.

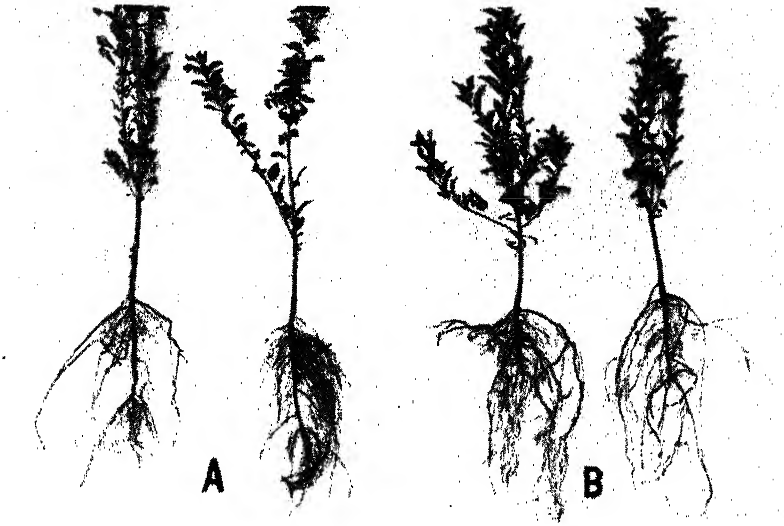

FIG. 3. Effects of organic matter on French Crab seedling roots. A, grown in soil with low organic matter; B, grown in soil high in organic matter.

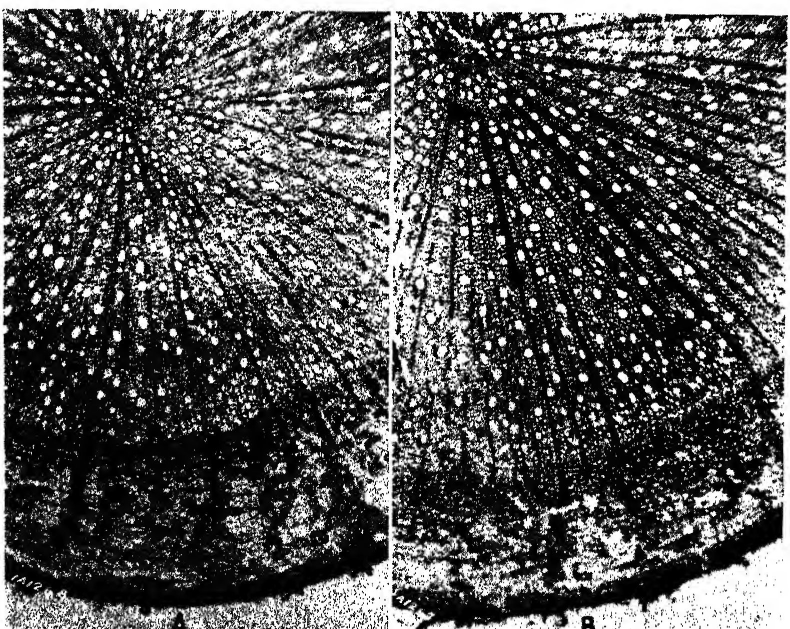

FIG. 4. Effects of fertilizer on French Crab seedlings. A, cross section of root grown in orchard soil; B, cross section of root grown in orchard soil to which was added ammonium phosphate.

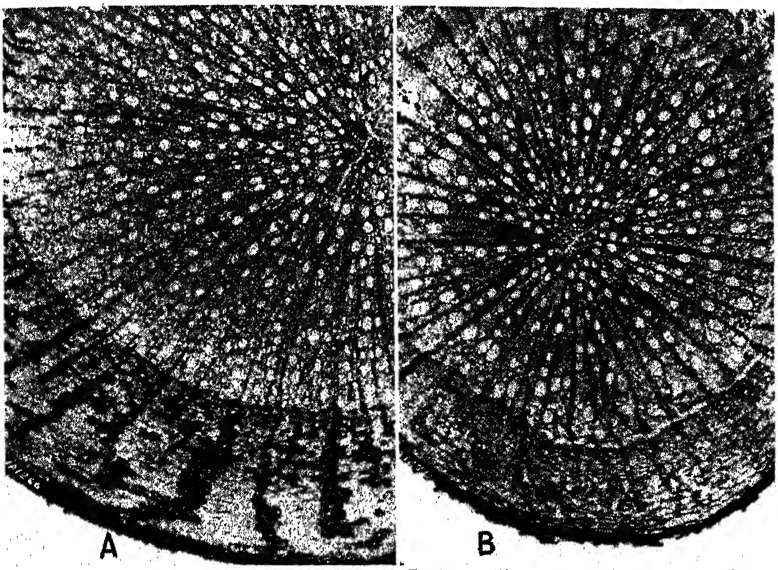

FIG. 5. Influence of water on French Crab seedling roots. A, cross section of root grown in soil with an abundant water supply; B, cross section of root grown in low moisture soil.

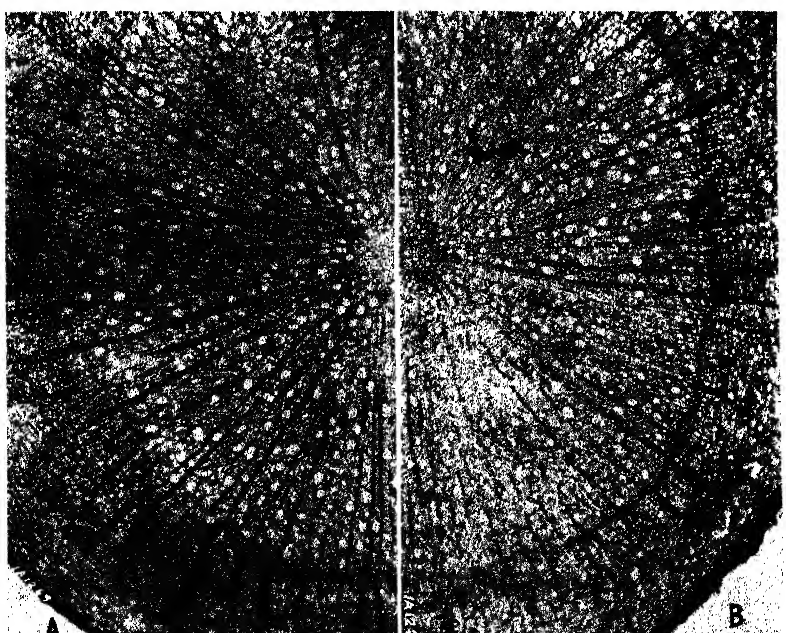

FIG. 6. Influence of organic matter on French Crab roots. A, cross section of root grown in a high organic soil; B, root grown in low organic soil.

The ratio of phloem to xylem is about the same in the two groups (Fig. 5A and B).

The number and size of vessels in the roots are about the same in group 5, grown in an abundance of organic matter, and in group 6, grown in sandy soil. The medullary rays were somewhat wider in roots of group 5 than those in group 6 (Fig. 6A and B).

These preliminary studies indicate that soils and soil treatments influence the morphology and to some extent the anatomy of French Crab seedlings. In order to compare the structure of different varieties of apple rootstocks it would seem necessary to grow them in the same type of soil and under similar soil management methods. Stionic effects also no doubt should be studied under similar soil treatments if comparisons are to be made.

It is proposed to continue the study of the effects of soils and soil treatments on French Crab seedlings and also study the stionic effects of selected French Crab rootstocks.

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Cold Hardiness of Malling Apple Rootstock Types as Determined by Freezing Tests

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LITTLE is known concerning the relative cold hardiness of the Malling rootstocks for apple trees. Their use is receiving increased attention in this country, especially in the Northeastern States. In this region the degree of resistance to winter injury is an important consideration in both nursery and orchard. It was the purpose of the present study to compare a number of the Malling rootstock types for resistance to low temperature injury.

Materials and Methods

Malling rootstocks used in this study were grown at the New York State Agricultural Experiment Station, Geneva, New York. They were furnished for the freezing tests through the courtesy of Dr. H. B. Tukey whose helpful interest and cooperation is hereby acknowledged.

The method of testing for cold hardiness has been described (1, 2) and involves the conductimetric estimation of electrolyte exosmosis from stems or roots as a result of freezing injury.

Experimental Results

Hardiness of Stems from 1-Year Rooted Layers:—Rooted layers from 10 Malling types were taken from stool beds late in November 1939, and placed in sand in a common storage nursery cellar at Geneva, New York. On March 6, 1940, 15 to 20 individuals from each type were selected at random, rejecting only those conspicuously overgrown or undersized. The trees were brought to the United States Horticultural Station, Beltsville, Maryland and tested for resistance to low temperature.

The basal etiolated portion of each layer was removed and the stem above this etiolated section cut into pieces 0.5 inch long. A 5-gram sample from each stem was frozen at –15 degrees F for a period of 16 hours. The remaining stem pieces were combined and 8 to 10 samples from each type left unfrozen to serve as controls. After determining the conductivity of the electrolytes exosmosed from the frozen and unfrozen samples, the latter were heated to boiling and the conductivity redetermined to obtain the value produced by complete death of the tissues.

Freezing injury increased the conductivity of the stems of all the types over that recorded for the unfrozen samples. However, differences in conductivity among the types were also found in the unfrozen samples as well as after killing them by heat. Consequently, in order to determine the magnitude of the differences necessary for statistical significance, the conductivity data were subjected to analysis of variance for groups of unequal numbers. The corresponding increments necessary for odds of 19: 1 and 99: 1 are presented in Table I. From

TABLE I—RELATIVE HARDINESS OF 1-YEAR MALLING CLONAL APPLE STEMS AS DETERMINED BY ELECTRICAL CONDUCTIVITY OF EXOSMOSED ELECTROLYTES AFTER FREEZING 5-GRAM SAMPLES AT –15 DEGREES F

Type	Specific Cond. $\times 10^{-6}$					
	Untreated	Boiled	Frozen*	Standard Error ±	Difference Between Frozen and Untreated	Standard Error ±
III	78	496	116	3.57	38	12.00
XIII	78	471	181	8.96	103	9.84
VII	91	433	194	4.29	103	9.52
XVI	76	437	188	5.91	112	9.13
IV	68	501	181	5.31	113	11.40
V	86	464	212	4.28	126	9.84
II	104	525	243	7.51	139	11.29
XII	71	526	219	5.42	148	10.56
IX	90	499	242	6.14	152	9.13
I	60	494	228	5.24	168	9.89

*Analysis of variance: between clons; df = 9, mean square 23,923**; within clons, df = 150, mean square 559.12. Difference necessary for odds of 19:1–16.7, 99:1–25.0.

these data it appears that freezing the stems of Malling III produced the smallest increase in conductivity of any of the types. Significantly more and progressively greater injury was measured in Malling XIII, VII, XVI, and IV, although the differences between these four types were not significant. The remaining five types were injured to a significantly still greater degree. It is of interest to note that the increase in conductivity caused by freezing the stems of Malling I was more than four times greater than with the stems of Malling III. This must represent actual differences in freezing injury since death of the stems by heat produced conductivities that were virtually identical for the two types.

Hardiness of Etiolated Stem Bases:—The basal or etiolated portions of the 1-year rooted layers from each type were combined and 5-gram samples frozen at the same time the stems were frozen. As would be expected they were in all cases injured much more than were the aboveground stems. Most injury as shown by greatest increase in conductivity was noted in Malling IX and IV and least injury in Malling III and XVI.

Hardiness of Roots:—On April 24, 1940, 10 trees from each of the 10 Malling types were dug from the nursery at Geneva, New York, and shipped to Beltsville. These trees had been lined out as rooted layers in the spring of 1939. The roots from many of the types were small and fibrous. Those tested ranged from 3 to 5 millimeters in diameter. They were cut into pieces 0.5 inch long and a 1-gram sample from each tree frozen at 20 degrees F for 16 hours. Results of the conductivity determinations are shown in Table II. These data were subjected to analysis of variance as for the stems. Because all roots were injured to a considerable extent by a temperature of 20 degrees, the differences between the types are not as great as with the stems. However, they do follow the same general order, the only exception being Malling XIII. Thus, roots of Malling III and VII showed least increase in conductivity due to freezing while the increases with roots of Malling I and II were very significantly greater.

TABLE II—RELATIVE HARDINESS OF 1-YEAR MALLING CLONAL APPLE ROOTS AS DETERMINED BY ELECTRICAL CONDUCTIVITY OF EXOSMOSED ELECTROLYTES AFTER FREEZING 1-GRAM SAMPLES AT 20 DEGREES F

Type	Specific Cond. $\times 10^{-6}$					
	Untreated	Boiled	Frozen*	Standard Error ±	Difference Between Frozen and Untreated	Standard Error ±
III	31	170	99	6.88	68	9.58
VII	27	151	95	4.82	68	8.57
XVI	30	177	108	4.90	78	8.37
IV	23	183	107	7.51	84	8.61
V	25	167	116	8.39	91	10.48
XII	30	189	124	5.31	94	10.91
IX	37	185	133	4.45	96	9.65
I	28	160	126	6.04	98	9.56
XIII	42	198	145	3.99	103	9.11
II	34	199	162	5.51	128	8.57

*Analysis of variance: between clons; df = 9, mean square 4,688**; within clons, df = 91, mean square 366.96. Difference necessary for odds of 19:1 = 17.0, 99:1 = 25.6.

Tukey and Brase have reported observations of the behavior of these Malling rootstocks in the nursery section of western New York during the period from 1928–38 (4). Within this period the rootstocks were subjected to the severe winter of 1933–34. None of the mother plants was killed outright although varying degrees of injury to the tops were recorded. During eight seasons (1928–35) 100 per cent survival of the six mother plants in each of five types was obtained (5). Of these Malling XVI, VII, V, and III were shown to possess superior hardiness by the present laboratory study. Only 50 per cent survival was obtained in the field tests with Malling IX. In the present study it was injured significantly more than the majority of the other types. Those showing a lower percentage of survival than Malling IX were not included in the present study. It should, of course, be recognized that failure of some of the types to survive under field conditions may be partly due to factors other than lack of cold hardiness.

The origin of many of the Malling clons is uncertain. Without doubt they differ greatly in genetic character. It would be very surprising if differences in potential cold hardiness were not present. All of the material tested in the present study was grown at one place under similar conditions. Likewise they were all frozen when dormant and presumably in the cold hardened condition. How much the resistance a stem or root offers to freezing may change even though still in the dormant condition is an important consideration but one not easily answered. Tukey has observed (3) the general order of bud start in the spring for the Malling rootstocks, and also the general order of maturity in the fall of the year (Table III). While it might be expected that there would be a direct relation between late maturing types and their susceptibility to low temperature, this does not seem to be the case. On the other hand there seems to be an inverse relation between the order of bud start and susceptibility to low temperature. Those types which start earliest in spring seem most injured by low temperature, as Malling IX, while those types which start latest in spring were least injured, as Malling XVI.

TABLE III—Comparison of Amount of Freezing Injury to Etiolated Bases From Rooted Layers with Order of Spring Foliation and Fall Maturity in Malling Rootstock Stems

Freezing Injury (Beginning With Least Injury)	Spring Foliation (Beginning With Earliest to Start)	Fall Maturity (Beginning With Earliest to Mature)
XVI	IX	II
III	IV	IX
XIII	VII	I
I	I	III
VII	V	IV
V	II	V
XII	III	VII
II	XIII	XII
IV	XII	XIII
IX	XVI	XVI

In considering the substitution of Malling rootstocks for the usual French Crab and variety seedlings the question of cold hardiness is certain to arise, at least in the colder regions of the country. The results of the present study afford no evidence as to the relative cold hardiness of our common seedling stocks compared with the Malling stocks. For such a study the Malling clons and seedling stocks should be grown under similar conditions at several different places. The present study indicates that relatively wide differences in hardiness occur even among the Malling types that appear best in the field. If these indications, such as the apparent outstanding hardiness of Malling III, are substantiated in later tests, considerable experimental time and money will have been saved in the search for the best rootstock from the standpoint of cold hardiness.

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Cold Hardiness of Seedlings From Certain Apple Varieties as Determined by Freezing Tests

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Abstract

This material will be published in full in a U. S. Department of Agriculture publication.

WITHIN the past decade nurserymen have been planting increasing numbers of seed from our domestic apple varieties for rootstock production. Formerly these rootstocks were produced mainly from imported French Crab seed. This year, owing to conditions abroad, it seems certain that little or no French Crab seed will be imported. The relative value as rootstocks of seedlings from different domestic varieties needs further investigation. The purpose of the present study was to compare the cold hardiness of roots from seedlings of a number of apple varieties.

Seed was obtained in 1937 from apples grown in the orchards of the United States Horticultural Station and the Maryland Agricultural Experiment Station at Beltsville, Maryland. Seedlings from 31 varieties (open pollinated) and 20 different combinations (hand pollinated) in which both parents were known were grown at Beltsville in 1938 and 1939. Controlled freezing tests employing the electrolyte exosmosis conductivity technique were made on 1-year roots in 1938 and on 1-year and 2-year roots and 1-year stems in 1939. Analysis of these data involving more than 3,000 determinations will be published elsewhere.

The results of the freezing tests reflect the well-known heterozygous character of apple varieties, revealing a very high variability in hardiness of their seedlings. The variability shown by seedlings resulting from open pollination was no greater than in progeny from known crosses. Seedlings from very hardy varieties as Oldenburg and Wealthy were not consistently hardier than seedlings of less hardy varieties such as Ben Davis and Grimes Golden. Analysis of variance in conductivity determinations with frozen 1-year roots of seedlings from 26 varieties shows only six varieties injured significantly more (odds of 99: 1) than the least injured variety. The least injured seedlings were from the Rome Beauty, Wealthy, Winesap, York Imperial, and Grimes Golden varieties. Those most injured were from the Winter Banana, Golden Delicious, Nero, Bonum, Williams, and King David varieties.

Greater differences in hardiness among varieties were noted in freezing tests with 2-year roots. Seedlings of Yellow Transparent, Gallia, and Winesap were injured significantly less than similar seedlings of Starking, Northwestern Greening, and Williams. In general, seedlings showing several different degrees of resistance to freezing injury were found in the progeny of each variety. While the proportion of hardy seedlings within a progeny varied from one variety to another, it could not be closely associated with the relative hardiness of the variety or of the pollen parent when known.

Terminal-Shoot Growth of Apple Varieties as Apparently Stimulated by Virginia Crab and Hibernal Intermediate Stocks

By M. T. Hilborn, *Maine Agricultural Experiment Station*, and J. H. Waring, *University of Maine, Orono, Me.*

COLD resistance is one of the most important factors in apple production in the northern latitudes. Surveys following several severe winters have disclosed heavier apple-tree losses in Maine than were reported to occur elsewhere in New England. Further, the chronic winter injury in Maine retards both growth and yield in practically all varieties. After the winter of 1933–34 about 40 per cent of the bearing apple trees in the State were reported to have been injured, but later observations on recovery of orchards made it apparent that the percentage of injury was actually greater than was first reported. Waring and Hilborn (19) indicated the possibility of reducing such loss to Maine growers by the use of hardy stocks, and a research program was initiated to determine, among other things, the relative growth and productiveness of comestible varieties branch-budded or -grafted on various intermediate stocks.

Virginia Crab and Hibernal were the varieties used first in this work —first of all Virginia Crab on the recommendation of F. C. Bradford,[1] but soon both varieties because of their demonstrated cold resistance and their desirable framework for topworking, as attested by Maney and Plagge (14). The value of hardy intermediate stocks in reducing loss from winter injury has been pointed out by many investigators. That their use may also increase the productivity of apple trees has been reported by Burkholder (3), Cullinan (4), Edgecombe and Lantz (5), Maney (10, 12), and McClintock (15) for Virginia Crab and Hibernal. Brown (2) also reported increased yield with Mammoth Black Twig as the intermediate stock.

Other varieties are being added to this study as they become available. Among such are Charlamoff and Antonovka although Blair (1) expressed a preference for Hibernal over Charlamoff, because of wider crotch angle and greater capability of supporting heavy loads of fruit. The importance of width of angle in relation to crotch injury has been emphasized by Horsfall and Vinson (18).

There seems to be justification now for a preliminary report dealing with Virginia Crab and Hibernal trees set at Orono in 1935 and 1936 and topworked by budding and whip-grafting through several years. Because of differences in age of scion growth, comparable data could be obtained only on 20 top varieties on Virginia Crab and five on Hibernal. It was desired to have each top variety represented several times on each intermediate stock, but in some cases differences in age have made comparison impossible. The number of trees forming the basis of the data here reported, therefore, varies from one to five of each top variety on each intermediate stock. Also represented in this

[1]Personal correspondence with J. H. Waring, 1934.

orchard, and in this report, are a few trees of several varieties of which each was worked on several clonal and seedling rootstocks.

Five topworked branches were selected in each tree, and on these the length of all terminal and lateral growth made in 1940 was measured. These growth data were used, in various combinations, for comparisons by Bessel's method to determine the significance of the difference between any two given means. Odds of 30:1 or better are considered significant.

Table I presents the average 1940 terminal growths of 20 varieties used as scions on Virginia Crab trunks. It is interesting to note the comparative ranking of some of the varieties, especially of those that are most prominent in the present composition of Maine orchards. Cortland is first of these in this ranking, but McIntosh, Richared, and Northern Spy are all near the bottom, all in the fourth quarter. Little or no significance is attached, however, to the ranking in Table I, considering how many factors influence growth. What seems important, however, is that these 20 varieties have made good growth. Maney (11) reported that Virginia Crab dwarfed Rhode Island Greening about 25 per cent. Lantz (9), McClintock (16), and Maney and Pickett (13) found a scion-dwarfing tendency resulting from Virginia Crab under several varieties. Goff, also, as reported by Roberts (18), observed many years ago that Virginia Crab was not a perfect stock for all varieties, Pewaukee being entirely incompatible with it. In Maine, however, there has been no evidence of dwarfing by Virginia Crab.

Eight of the varieties listed in Table I were represented in this orchard on various rootstocks. In Table II the growth of each of these varieties on a clonal or a seedling rootstock but with its own trunk is compared with the growth on a Virginia Crab intermediate stock forming the trunk on a seedling rootstock. In every such comparison, very high odds indicate an invigorating effect of the Virginia Crab

TABLE I—AVERAGE 1940 TERMINAL GROWTH OF VARIETIES TOPWORKED ON VIRGINIA CRAB

Variety	Average Terminal Growth (Cms)*
Lodi	93.4±2.49
Early McIntosh	90.2±7.18
Starking	86.6±3.50
Red Spy	85.6±3.00
Melba	83.6±2.46
Cortland	82.0±4.59
Baldwin	81.2±3.30
Duchess	80.0±3.02
Red Duchess	75.6±4.01
Delicious	74.4±3.82
Gravenstein	72.4±2.58
Rhode Island Greening	70.6±2.86
Newfane	70.2±1.21
Red Gravenstein	70.0±3.12
Golden Delicious	68.6±1.65
Winter Banana	63.6±0.87
McIntosh	58.8±1.79
Richared	58.4±2.86
Wealthy	57.6±1.73
Northern Spy	47.4±1.70

*First 10 mostly are significantly greater than second 10.

TABLE II—AVERAGE 1940 TERMINAL GROWTH OF SEVERAL VARIETIES WHEN WORKED ON VARIOUS ROOTSTOCKS VS. WHEN TOPWORKED ON VIRGINIA CRAB WHICH WAS WORKED ON SEEDLING ROOTSTOCKS

Variety	Worked on Various Rootstocks		Growth (Cms) When Worked on Virginia Crab Trunks with Seedling Rootstocks
	Rootstock Variety	Growth (Cms)	
Baldwin	Malling I	42.4 ±3.46	81.2 ±3.30
Baldwin	Malling II	43.4 ±2.37	81.2 ±3.30
Baldwin	Malling XIII	43.6 ±1.65	81.2 ±3.30
Delicious	Malling XIII	36.4 ±1.54	74.4 ±3.82
McIntosh	Malling I	13.8 ±0.59	58.8 ±1.79
McIntosh	Malling II	20.2 ±1.52	58.8 ±1.79
Melba	Seedling	58.6 ±1.19	83.6 ±2.46
Red Spy	Seedling	35.4 ±2.12	85.6 ±3.30
Richared	Seedling	44.4 ±1.17	58.4 ±2.86
Starking	U.S.D.A. 227	42.8 ±1.47	86.6 ±3.50
Wealthy	Seedling	35.2 ±4.74*	57.6 ±1.73*

*With odds high that the difference from growth on Virginia Crab is significant; all others have odds very high.

intermediate over direct propagation of the scion variety on the rootstock.

Similar comparisons are made in Table III, but with Hibernal as the intermediate stock. Compared with Delicious on Malling XIII, significant odds were not obtained for better growth with Hibernal intermediate. In the other comparisons, highly significant differences in growth favored the use of the intermediate stock. It appears, then, that both the Virginia Crab and the Hibernal varieties have invigorated the scion varieties included in these comparisons. Many investigators, have reported similar results. In Table IV, comparisons are made of the growth of five scion varieties on Virginia Crab trunks with their

TABLE III—AVERAGE 1940 TERMINAL GROWTH OF SEVERAL VARIETIES WHEN WORKED ON VARIOUS ROOTSTOCKS VS. WHEN TOPWORKED ON HIBERNAL WHICH WAS WORKED ON SEEDLING ROOTSTOCKS

Variety	Worked on Various Rootstocks		Growth (Cms) When Worked on Hibernal Trunks with Seedling Rootstocks
	Rootstock Variety	Growth (Cms)	
Baldwin	Malling I	42.4 ±3.46	64.4 ±2.26
Baldwin	Malling II	43.4 ±2.37	64.4 ±2.26
Baldwin	Malling XIII	43.6 ±1.65	64.4 ±2.26
Delicious	Malling XIII	36.4 ±1.54*	43.6 ±1.86*
Starking	U.S.D.A. 227	42.8 ±1.47	70.2 ±4.55

*Difference not significant; all others have odds very high.

TABLE IV—AVERAGE 1940 TERMINAL GROWTH OF SEVERAL VARIETIES WHEN TOPWORKED ON VIRGINIA CRAB VS. ON HIBERNAL

Variety	Virginia Crab Trunks	Hibernal Trunks
Baldwin	81.2 ±3.30	64.4 ±2.26
Cortland	82.0 ±4.59	49.2 ±3.31
Delicious	74.4 ±3.82	43.6 ±1.86
Northern Spy	47.4 ±1.70*	49.8 ±1.28
Starking	86.6 ±3.50*	70.2 ±4.55

*Difference not significant; all others have odds very high.

growth on Hibernal trunks. In Baldwin, Cortland, and Delicious, differences in terminal growth were highly significant favoring Virginia Crab. With Starking the difference likewise favored Virginia Crab, but fell just short of the standard of significance. With Northern Spy, the small difference in terminal growth on the two trunk varieties lacked any significance.

It must be remembered, however, that all the data presented here have been obtained from trees in which the growth from the top scions was not more than 4 years old. Observations will be continued on these trees to see if this apparent invigoration will continue or if dwarfing will occur. It is not known what will happen when the trees are so completely topworked that all the Virginia Crab foliage is removed. Heinicke (7) reported on the influence of the scion leaves on the character of fruit produced by the stock. Hedrick (6) also noted that the food elaborated by the foliage of the scion may be different from that which the stock would have had with its own foliage. It also is not known what effect increased age of both the stock and scion will have. Morris (17) stated that the differences in bud growth between varieties when topworked and when not topworked were less marked the second year. All the data reported here were obtained from scion growth at least 3 years old, but the differences noted may be lessened with an increase in age.

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Three-Year Performance of Sixteen Varieties of Apples[1] on Malling IX Rootstocks

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BECAUSE of current interest in dwarf apple trees on the Malling IX rootstock for home and garden planting and the demand for more detailed performance records of such trees, the following data, preliminary in nature, are presented. They give the records of 16 varieties for 3 years after planting and include figures on tree survival; height, spread, and trunk diameter; blossom number and set; and number, weight, and size of fruit harvested.

MATERIAL AND METHODS

The Malling IX rootstocks were raised as layers from material secured from the East Malling Research Station. One hundred and twenty trees propagated on these rootstocks and headed at 18 inches in the nursery were set 15 by 15 feet in the orchard as 2-year-old trees in the spring of 1938. The following varieties were included: Baldwin, Cox Orange, Early McIntosh, Gallia, Rhode Island Greening, Grimes, Jonathan, Tompkins King, McIntosh, Northern Spy, Red Spy, Stark, Turley, Wagener, Winesap, and Wolf River.

Two rows comprising 80 trees were set in sod, and a third row of 40 trees was set in plowed sod. All were mulched with straw thereafter and kept in sod mulch. The soil is a fertile one (Ontario stony loam). Ammonium sulfate, 1 pound to the tree, was applied the second and third years after planting. To avoid interference with varietal fruiting and general growth habits very little pruning was done.

RESULTS FIRST YEAR PLANTED

All of the trees survived the first growing season and grew as vigorously as or more vigorously than trees of similar varieties on standard rootstocks. Strong terminal growth, large leaf size, and dark green color of foliage were characteristic features. On the other hand, the number of lateral buds that developed into shoots was smaller than typically occurs with the same varieties on standard rootstocks, a fact which may explain the relatively strong terminal shoot growth observed. There were a few scattered blossoms the first year the trees were planted, but no fruit was harvested (Table I).

RESULTS SECOND YEAR AFTER PLANTING

In the second year after planting, the trees again made strong terminal growth, blossomed and fruited (Table I). Several trees died during the season from what was diagnosed by pathologists as "collar rot" associated with winter injury. Examination showed the initial injury to occur at the ground level without regard to whether it was

[1]Journal Article No. 430 of the New York State Agricultural Experiment Station.

TABLE I—Blossoming and Fruiting First and Second Growing Seasons

Variety	Blossoming	Fruiting		Blossoming	Fruiting	
		Number Trees	Number Fruits		Number Trees	Number Fruits
	First Year			*Second Year*		
Baldwin	O-VL*	2	2	M-MF	3	5
Cox Orange	O-VL	0	0	M-F	1	4
Early McIntosh	VL-F	0	0	M-F	1	4
Gallia	L-M	0	0	L	3	10
Grimes	M-F	0	0	O-VL	1	1
Jonathan	VF	0	0	VF	3	8
McIntosh	L-M	0	0	F	1	1
Northern Spy	O	0	0	LtoM	1	1
Red Spy	O	0	0	VL	0	0
R. I. Greening	L-MF	1	1	M-F	4	5
Stark	L-M	0	0	F	3	9
Tompkins King	O-M	0	0	O-F	0	0
Turley	O-L	0	0	F	1	3
Wagener	O-VL	0	0	M	3	12
Winesap	L-M	0	0	M-MF	0	0
Wolf River	VL	0	0	L-M	3	7

*O = none; VL = very light; L = light; M = moderate; MF = moderately full; F = full; VF = very full.

the scion or the rootstock which was first affected, and resulted in the girdling of the tree. The injury spread slowly throughout the season, both upward into the scion and downward into the rootstock, most extensive invasion being into the rootstock, resulting in death of the entire root system and eventual drying out and death of the top.

Results Third Year After Planting

In the third year after planting, the trees continued to show vigorous growth and dark green foliage except for a few additional trees affected with "collar rot". The strong terminal growth and large size and good color of leaves were again characteristic. As the trees began to fruit, the more slender branches were inclined to spread and droop, thus accentuating the lowness and spread of the trees and their dwarf nature. The general shape of the trees is indicated in Table II which gives the

TABLE II—Tree Survival, Average Height, Spread, and Trunk Diameter at End of Third Growing Season

Variety	Trees		Height (Inches)	Spread (Inches)	Trunk Diameter 12 Inches Above the Ground (Mm)
	Number Planted	Number Dead by Third Year and Cause of Death			
Baldwin	10	1 Collar rot	68	63	32
Cox Orange	10	1 Mice	73	58	35
Early McIntosh	13	2 Mice, collar rot	71	49	31
Gallia	5	2 Collar rot, blight	69	42	28
Grimes	5	0	66	48	31
Jonathan	5	1 Blight	63	51	28
McIntosh	2	0	63	60	30
Northern Spy	25	2 Collar rot	80	45	37
Red Spy	5	0	70	34	27
R. I. Greening	5	0	60	58	30
Stark	5	2 Collar rot, blight	70	70	36
Tompkins King	5	3 Collar rot, blight	78	54	35
Turley	4	2 Collar rot	69	54	29
Wagener	10	0	61	36	27
Winesap	5	0	78	67	33
Wolf River	5	0	77	72	33

average height and spread as well as the trunk diameter. Yet each variety developed a characteristic habit of growth quite aside from general shape. For example the branches of Gallia were few, thin, weak, and drooping, and tended to bear fruit near the ends and to break under the load, whereas branches of Cox Orange were more numerous, more sturdy, and tended to carry the fruit inside the tree, resulting in a compact, substantial tree. Additional characteristics are given for each variety later in this report.

Blossoming:—All varieties blossomed a week to 10 days earlier than the same varieties on French Crab seedling rootstocks. The average number of blossoms for each tree, together with the number of blossoms set are given in Table III. Not only was the number of blossoms high, but the percentage set was also high, necessitating heavy thinning to prevent overloading. The small blossom drop appeared characteristic of trees on the Malling IX rootstock.

Yield of Fruit:—The number of fruits carried to maturity was, excepting for trees with very light load, less than half the number of fruits remaining following thinning, and seemed in general associated with the vigor and ability of an individual tree to carry a given number of fruits through to maturity. For example, the vigorous Stark variety matured an average of 38 fruits out of an average of 67 remaining after early-season thinning, whereas the less vigorous Jonathan variety matured only 24 out of 162 remaining after early-season thinning. The figures for number and weight of fruits are given in Table III.

Maturity, Quality and Size of Fruit:—The fruit matured from a week to 10 days earlier on the Malling IX rootstock than on French Crab seedling rootstocks, representing about the same difference as was observed in the earlier blossoming of trees on the Malling IX rootstock. Fruits of Cox Orange, left until the usual picking time for this variety, developed severe water core, indicating over-maturity at that date. Such varieties as Wagener and Turley, which in some cases fail to properly mature, were on these trees, fully matured.

The fruits of red-colored varieties developed especially high color.

TABLE III—Bloom, Set, and Yield of Fruit on per Tree Basis During Third Growing Season (1940)

Variety	Number Blossoms	Number Set	Fruit Remaining After Thinning	Fruit Harvested		
				Number	Pounds	Highest Individual Tree (Pounds)
Baldwin	199	137	80	34	13.5	17
Cox Orange	86	72	49	16	6.7	13
Early McIntosh	287	225	142	74	13.6	20
Gallia	67	48	22	12	3.6	4
Grimes	207	167	83	41	12.4	16
Jonathan	247	217	162	24	4.5	8
McIntosh	189	140	114	61	12.3	15
Northern Spy	63	46	23	13	4.9	16
Red Spy	5	4	2	2	.8	1
R. I. Greening	106	55	42	24	12.2	17
Stark	119	49	67	38	16 7	19
Tompkins King	35	8	8	2	1.2	2
Turley	49	21	16	6	1.7	3
Wagener	106	56	42	15	5.5	10
Winesap	13	12	9	4	1.8	3
Wolf River	34	34	14	11	8.8	14

TABLE IV—Size and Uniformity of Fruit from Trees on Malling IX Rootstocks (1940)

Variety	Per Cent of Fruit in Each Diameter Class				
	Above 3 Inches	3 Inches	2¾ Inches	2½ Inches	Below 2½ Inches
Baldwin	62	29	8	1	0
Cox Orange	39	30	30	1	0
Grimes	0	10	41	42	7
Jonathan	13	28	40	19	0
Northern Spy	67	29	4	0	0
Wagener	56	22	14	8	0
Winesap	20	40	28	12	0

Such varieties as Stark, which in New York State seldom attain high color, developed attractive red color; Cox Orange, which is seldom attractive, developed an attractive yellowish-orange color overlaid with dark red stripes and splashes; and Grimes, which frequently shows a greenish color, developed an attractive yellow.

The size of the fruit was slightly above that typical of the variety. More significant perhaps, was the general uniformity of the fruit (Table IV), a characteristic usually associated with trees which have reached an "adult" condition, as contrasted with the fruit of young trees on seedling rootstocks which is characteristically of uneven sizes. This difference was more striking than the table indicates, inasmuch as it shows the average of the fruit on all the trees for a given variety. On any one tree the fruits were remarkable similar in size, being larger, but uniformly so, on trees bearing lighter crops, and smaller, but again uniformly so, on trees bearing heavier crops.

General Characteristics of Varieties on Malling IX Rootstocks at Geneva

Baldwin: — Tree — sturdy, low, inclined to spreading (Fig. 1). Shoots—very vigorous, sturdy, good diameter. Leaves—very large, thick, dark green. Blossoming—light first year, medium second year, full third year, set heavy. Fruiting—very light first year, light second year, full third year, inclined to set in clusters, borne both terminally and on spurs, dark color, large size. Well suited to Malling IX rootstock and use as garden plant.

Cox Orange:—Tree — upright-spreading, symmetrical. Shoots — vigorous and numerous, good diameter, sturdy. Blossoming—light first year, medium second year, medium third year, set heavy. Fruiting—none first year, light second year, good third year, well distributed, inside tree on spurs, large size, uniform, excellent color. Well suited to Malling IX rootstock and use as garden plant.

Early McIntosh:—Tree—roundish. Shoots—moderately vigorous, yellowish cast. Leaves—large, thick, dark green. Blossoming—medium first year, medium full second year, very full third year, set heavy. Fruiting—none first year, light second year, heavy third year, requires thinning, well-distributed, inside tree on spurs, uniform, excellent color. Well suited to Malling IX rootstock, early fruiting, good garden plant.

Gallia:—Tree weak, unsymmetrical. Shoots—thin diameter, few, willowy, inclined to break, subject to collar rot and fire blight. Leaves

FIG. 1. Two-year-old trees of (left) Baldwin/Malling IX and (right) Grimes Golden/Malling IX (third growing season).

—medium size, light green. Blossoming—light to medium first, second, and third years, set medium. Fruiting—none first year, light second and third years, on terminals, uniform, good size, high color. Unsuited to Malling IX rootstock; too weak and dwarfish for good garden plant.

Grimes:—Tree—ovate, compact, symmetrical (Fig. 1). Shoots—vigorous, sturdy, good diameter. Leaves—medium in size. Blossoming—medium first year, light second year, heavy third year, set heavy. Fruiting—none first year, light second year, full third year, on spurs, inside tree, well distributed, good size, attractive yellow, well matured. Well suited to Malling IX rootstock, good garden plant.

Jonathan:—Tree—compact, symmetrical, subject to blossom blight but without severe advance into branches. Shoots—moderately vigorous, not overly sturdy. Leaves—medium in size. Blossoming—very full beginning first year planted and continuing each year, set heavy. Fruiting—none first year, light second year, full third year, requiring heavy thinning, on spurs, inside tree, well distributed, medium size, uniform, high color, well-matured. Well suited to Malling IX rootstock, inclined to be only moderately vigorous, heavy and early blossoming and fruiting, good garden plant.

McIntosh:—Tree—inclined to spreading, somewhat scraggly, not symmetrical. Shoots — moderately vigorous, inclined to be slender, drooping, bark yellowish "off color". Leaves—variable in size, some large, mostly small. Blossoming—light to medium first year, full second year, full third year, set heavy. Fruiting—none first year, light second year, full third year, on terminals and on spurs inside tree, well distributed, medium size, uniform, high color, tends to over bear. Inclined

to be lacking in vigor on Malling IX rootstock, only fair as garden plant.

Northern Spy:—Tree—upright, pyramidal (Fig. 2). Shoots—very vigorous, sturdy, good diameter. Leaves—very large, thick, dark green. Blossoming—none first year, light second year, moderate third year, set moderate. Fruiting—none first year, very light second year, moderate third year, both terminally and on long spurs inside tree, large size, uniform, well-matured, excellent quality, color somewhat dull. Well suited to Malling IX rootstock, makes larger tree than most varieties.

Red Spy:—Tree—upright, pyramidal. Shoots—vigorous, very sturdy. Leaves—large, thick, dark green. Blossoming—none first year, very light second year, very light third year. Fruiting—none first two years, very light third year, fair color. Well suited to Malling IX; in comparison with Northern Spy similar to that variety but less vigorous, more compact, and later and more shy in both blossoming and fruiting.

Fig. 2. Two-year-old tree of Northern Spy/Malling IX (third growing season).

R. I. Greening:—Tree—low, spreading. Shoots—very vigorous, large diameter, sturdy. Leaves—very large, thick, dark green. Blossoming—moderate first year, moderately full second year, moderately full third year, set proportionately high. Fruiting—very light first year, light crop second year, full crop third year, on spurs, inside tree, well distributed, large, uniform, frequently blushed. Well suited to Malling IX rootstock, vigorous, early and regular bearer.

Stark:—Tree—upright-spreading, compact, symmetrical, subject to collar rot. Shoots—very vigorous, good diameter, sturdy. Leaves—very large, thick, dark green. Blossoming — light first year, full second year, moderately full third

year, moderate set. Fruiting—none first year, light second year, full third year, on spurs, inside tree, well distributed, large, uniform, highly colored. Well suited to Malling IX, except for collar rot, vigorous, early and heavy bearer.

Tompkins King:—Tree—upright-spreading, scraggly, subject to collar rot. Shoots—vigorous, few, long. Leaves—large, thick. Blossoming—light first year, light second year, light third year, set light. Fruiting—none first two years, light third year, terminally, large, uniform, dull color. Compatible with Malling IX but lacking in tree and fruiting qualities for good garden plant.

Turley:—Tree—upright-spreading, somewhat scraggly, subject to collar rot. Shoots—vigorous, few, long. Leaves—large, thick, dark green. Blossoming—light first year, full second year, moderate third year, set light. Fruiting—none first year, light second year, light third year, terminally, large, uniform, high color. Compatible with Malling IX but lacking in tree and fruiting characters for good garden plant.

Wagener:—Tree—inclined to ovate, low, compact, blights somewhat. Shoots—moderately vigorous, sturdy. Leaves—large, thick, dark green. Blossoming—very light first year, moderate second year, moderately full third year, set moderately full. Fruiting—none first year, light second year, moderate third year, both terminally and on spurs inside tree, well distributed, good size, uniform, high color. Well suited to Malling IX, making small compact garden plant.

Winesap:—Tree—upright-spreading, scraggly, larger than most varieties. Shoots—very vigorous, somewhat thin diameter. Leaves—large. Blossoming—light first year, medium to full second year, light third year, set poor. Fruiting—none first two years, light third year, on terminals, scattered, medium size, dull color. Compatible with Malling IX but lacking in tree and fruiting qualities for good garden plant.

Wolf River:—Tree—upright-spreading, scraggly, unsymmetrical. Shoots—long, very vigorous, need support. Leaves—very large, thick, dark green. Blossoming—very light first year, moderate second year, moderate third year, set moderate. Fruiting—none first year, light second year, moderate third year, clustered on spurs, very large, high color. Compatible with Malling IX, inclined to spreading, unsymmetrical tree, and to clustering of fruit.

Comparison of Domestic Apple and French Crab Seedlings as Stocks under Orchard Conditions[1]

By A. L. SCHRADER and I. C. HAUT, *University of Maryland, College Park, Md.*

THIS study was made to determine under orchard conditions the behavior of apple varieties propagated on several seedlings of domestic apple seed sources, as compared to French Crab seedlings. In 1930, 1-year-old trees[2] of Stayman Winesap, Starking, York Imperial and Gallia Beauty were set in an orchard planting, 20 by 20 feet apart, at the Maryland Horticultural Farm near College Park, Maryland. The site of the orchard was on a well-drained, Sassafras loam soil. Each of the four varieties had been propagated by budding on six understocks, including commercial French Crab seedlings, and seedlings of Northern Spy, Rome, Tolman, McIntosh, and Fameuse, obtained from open-pollinated seeds of these varieties, as collected from two orchard sources, namely, Arlington Farm, Virginia and South Haven, Michigan.

The arrangement of the plots was planned so as to randomize the six understocks to permit the use of analysis of variance with each variety. Hence, five blocks were used, with each understock occurring once in each block, and the six understocks randomized with each of the four varieties. The four varieties occurred in each block as two rows each but were not randomized in the blocks owing to the necessity for maintenance of uniform pollination conditions. A single plot of a given variety on a given understock consisted of four trees arranged in a square.

The season of 1930 was very unfavorable as the result of a prolonged summer drouth and a number of the trees died, particularly of Gallia Beauty and York. However, Starking and Stayman maintained a very good stand of trees. Trees that were lost in 1930 were replaced with 2 year old trees in 1931, which grew nearly as well as the original trees but have not been considered in the final calculations of results. These replants did serve to maintain a complete stand of trees so that no trees were favored by blank spaces. In no case was there a complete loss of all four trees from any given plot.

Annual trunk circumference measurements in millimeters and annual yields per tree were secured to determine the responses of these trees. At the end of the 1938 season it was necessary to remove three of the trees from each plot as the trees became too crowded for good orchard management. All trees received the usual commercial care in spraying, and so on, except that the minimum of pruning was done to eliminate variation due to pruning differences. At the present time, only the Starking and York Imperial trees are remaining in the orchard with five trees for each understock for a given variety.

[1]Scientific Contribution No. 533, Department of Horticulture, Maryland Agricultural Experiment Station.

[2]The Bureau of Plant Industry, U. S. Department of Agriculture, through Mr. G. E. Yerkes and Dr. F. E. Gardner, cooperated in this investigation by propagating and furnishing the trees for this experiment.

Results

In Table I, the trunk circumference increases and yields are presented as averages per tree, each figure representing the average of five randomized plots of four trees each (with the exception of a few plots where less than four original trees remained). Interpreting the data broadly, there are no differences of real importance among the understocks except possibly with Gallia Beauty and even here there were no differences in yield, and the growth differences were only significant to the 5 per cent point. With Starking, it is difficult to emphasize the significance of yield differences, due to the relatively low yields recorded for this variety; and the poorer growth on Fameuse and McIntosh, although significant statistically, is not of great magnitude. In fact, the largest difference in growth as calculated on the basis of square area of trunk cross-section, is less than 20 per cent. Considering the poorer growth of Starking on McIntosh, this does not agree with the results obtained by Yerkes and Sudds (2) with this same combination in West Virginia, although it is difficult to compare results as the two experiments were not arranged in the same way nor were the results analyzed in the same manner.

TABLE I—Growth and Yield of Four Apple Varieties on Six Seedling Understocks, Five of Which Were From Open-Pollinated Seeds of Domestic Apple Varieties

Understock	Trunk Circumference Increase 1931 to 1938 Inc.				Yields per Tree (Bushels)		
	Starking	Stayman	York	Gallia Beauty	Starking	Stayman	Gallia Beauty
French Crab........	394.4	335.2	374.2	351.4	4.17	7.70	8.00
Northern Spy.......	402.5	324.5	370.2	——	3.38	8.83	8.00
Fameuse...........	372.6	359.5	386.8	319.4	2.44	10.03	6.62
Tolman............	387.7	323.3	384.0	309.9	4.24	8.92	7.03
McIntosh..........	361.3	348.7	360.9	——	2.70	9.88	8.27
Rome..............	393.1	353.3	370.1	320.9	2.54	7.45	6.67
Difference necessary for significance 5% / 1%	26.6	No significance	No significance	25.3	1.32 1.75	No significance	No significance
"F" Value	23.5	2.03	0.29	4.10	3.31	2.06	1.39

All of the six understocks behaved similarly when used under Stayman and York, and this fact, together with the lack of great significance for differences with the other varieties, leads one to believe that more carefully controlled field experiments would show little or no difference among the seedling stocks which were used in this work.

Another point in favor of this view is that the circumference growth averages for all varieties in this experiment, although not subject to statistical treatment, were very close together, as follows, French Crab 363.8 millimeters, Northern Spy 365.7 millimeters, Fameuse 359.5 millimeters, Tolman 351.3 millimeters, McIntosh 357.0 millimeters, and Rome 359.3 millimeters.

Open pollinated seedlings, of course, would be affected somewhat by the male parent, as shown by Gardner (1), and hence this factor

might be of some importance in applying results of studies with open-pollinated seedlings. However, in this experiment, the seeds from South Haven and Arlington Farm orchards, behaved similarly.

Summary

Four apple varieties, Starking, Stayman, York and Gallia Beauty, with few exceptions, tended to behave alike whether grown on French Crab seedlings or open pollinated seedlings of Northern Spy, Fameuse, Tolman, McIntosh, or Rome. It is indicated that Starking grew somewhat poorer on Fameuse and McIntosh and Gallia was poorer on Fameuse, Tolman and Rome, but reasons have been indicated that too much weight should not be placed on these differences.

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Seedling Apple Stocks of Known Origin in Nursery and Orchard Tests

By G. E. YERKES, *U. S. Horticultural Station, Beltsville, Md.*, and R. D. ANTHONY, *Pennsylvania State College, State College, Pa.*[1]

THE principal apple stocks in current use by nurserymen are from seed either of French Crab or American orchard varieties. The term French Crab comprises a number of varieties of a type of apple grown in Europe for cider making. The fruit has no market value in this country. The trees are grown here occasionally but the commercial supply of seed is imported in amounts up to several thousand pounds annually. French Crab has been the leading stock for at least 40 or 50 years and is the foundation for a large proportion of our present bearing orchards. Although it is preferred by many experienced nurserymen and orchardists, the present trend is to American seed. In recent years perhaps as much as half the seed supply has been from orchard varieties, largely the sorts grown in the Pacific Northwest.

Most of the American seed is washed from cider pomace or evaporator waste as a by-product to be had in any desired quantity at low cost, as the seed is easily separated in water. Like French Crab, little discrimination is made among varieties for the bulk of the commercial supply. This mixed seed, properly cared for, usually germinates well except that a proportion is damaged by the knives and the presses of modern cider mills. The selection of particular varieties for seed would add to its cost, but an adequate supply of seed from the prominent commercial sorts could be secured without difficulty. Any improvement over mixed seedlings to be obtained by this kind of selection could be accomplished with little change in nursery procedure compared to the cultivation of trees specially for their seed or developing proven clons adapted to a wide range of conditions.

Certain clonal stocks offer much promise. Such ones as Virginia Crab, Hibernal and Haralson are resistant to cold and the Malling types are valuable for specific purposes such as various degrees of dwarfing. Although the use of these clonal stocks may be expanded materially, it is likely that seedlings will continue to predominate for many years to come.

The use of seedlings from cultivated varieties of apples for stocks goes far back into horticultural history. It was a standard practice among nurserymen of early American times to wash out the seed they needed from the pomace of some nearby cider mill. As these early nurseries were located mainly in New York and Southern New England, seedlings of our hardier varieties formed the foundation of the commercial orchards of this period. In later times with the wide expansion of apple culture French Crab came into general use and the 1-year-old seedlings grown in France, as well as seeds, were imported in large quantities. Quarantine restrictions with the object of reducing the danger of importing plant pests and eventually the Federal embargo

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on seedlings for stocks were among the influences that renewed attention to American production of seedlings from domestic seed as well as from French Crab.

In experiments with seedling apple stocks of known maternal parentage by the United States Department of Agriculture most attention has been given to widely grown varieties because seed from them is available for general use, although seedlings from some of the less prominent sorts also have been grown annually for several years. The seed was obtained from several sources, mainly from the experimental orchard at Arlington Farm and through the cooperation of the Michigan Experiment Station by Stanley Johnston at South Haven.

In germination of seed and size of 1-year-old seedlings, the progeny of a number of varieties compares favorably with French Crab under cultural methods similar to those practiced in seedling nurseries. A list of those varieties from which three or more annual crops produced good percentages of usable seedlings includes Ben Davis, Delicious, Fameuse, Florence Crab, Gano, Golden Russett, Grimes Golden, Jonathan, King David, Martha Crab, McIntosh, Missouri Pippin, Northern Spy, Oldenburg, Rasmussen, Red Siberian crab, Rome Beauty, Shiawassee, Smith Cider, Tolman Sweet, Wagener, Wealthy, Whitney crab, Winesap, Winter Banana and York Imperial.

Within each lot a wide variation in size was always found when the 1-year plants were graded. In many cases about one-half to two-thirds were of usable size, about equally divided between grades one and two. It should be noted that size and length of roots are influenced very much by the texture and depth of the soil and by the spacing as well as the inherent characters of the seed.

In deep sandy loam most seedlings develop long tap roots with few branches. This form is wanted for piece-root grafting but short main roots with well distributed branches are preferable for budding. Seedlings of a few varieties have some natural tendency to this form of root, especially Fameuse, Kinnard, Jonathan, Delicious, Ben Davis and York Imperial, but none compares favorably with those branch root seedlings produced artificially by large growers in the Pacific states by the expedient of cutting under during early summer when the seedlings are but a few inches tall.

The inroads of woolly aphis cause the loss of many apple roots not only in the first year seedlings but during the succeeding two seasons after lining out for budding. While the percentage of loss of trees from woolly aphis is larger in the nursery than that after the trees are transplanted to the orchard, aphis damage continues. Seedlings of most American varieties are susceptible, like French Crab, to the attacks of woolly aphis. Even Northern Spy seedlings are often attacked, although many of these escape injury. Entz crab also has indications of aphis resistance in its seedlings but the hard texture of the roots is objectionable and they do not withstand transplanting as well as seedlings of better known varieties.

In cooperation with the state Experiment Stations, orchard plantings of varieties budded on some of these seedling stocks have been started in the Shenandoah-Cumberland region and other places where

the apple is an important crop. Several of them have reached bearing age but the crops have not been large or consistent enough to give a good index to the influence of the stocks. The relative size of the trees as indicated by the trunk measurements is the most feasible means of comparison. The York Imperial and Gallia Beauty trees to be referred to here were set out in 1930.

The stocks were from seed planted in 1927. The 1-year-old seedlings were selected to include only those 3/16 to 1/4 inch in diameter. They were lined out and budded in 1928. The growth from the buds in 1929 was confined to single stems by pinching out all laterals soon after they started. Intermediate size trees were selected for planting and the several lots were as nearly uniform in size as the limited number of each lot would afford.

One orchard from this propagation was planted at the Maryland Experiment Station. A paper on the results there is being presented at this meeting, by Dr. A. L. Schrader.

The orchards shown in Tables I and II are located in southern Pennsylvania on gravelly loam. This soil is composed of a thin layer of detritus from the sandstone foothills of Blue Mountain overlying the Hagerstown limestone. Except where the subsoil is imperfectly drained this is good orchard soil. These orchards have received clean culture.

In Table I, York Imperial trees on Delicious seedlings are shown to be considerably larger than on Gano, Ben Davis or either of the two French Crab sources. These two French Crabs were among the largest trees in a collection of some 20 French Crab varieties at Arlington Farm. As the trees of the different sorts varied greatly in size, it was expected that the seedlings of the most robust trees might prove better as stocks than commercial mixed seed. This did not prove to be the case in the nursery stage where the progeny of these named sorts and from imported mixed seed were virtually equal in growth. At the present stage of development in this orchard their influence on York Imperial differs to a significant degree.

Another orchard of York Imperial near the preceding one has trees on Wealthy seedlings that are a little larger than those on Winesap

TABLE I—York Imperial on Seedling Stocks Planted April 1930, Franklin County, Pennsylvania (Gillan Brothers Orchard)*

Maternal Parents of Seedling Stocks	No. Trees	Mean	Standard Deviation	Odds in Favor of Delicious
Orchard No. 1				
Delicious	15	291± 7.25	29.85	——
French crab (Bonne de Freuilles)	23	228±10.16	70.67	Large
Gano	29	213± 7.52	59.00	Large
French crab (Julian le Paulmier)	17	147± 7.82	46.35	Large
Ben Davis	15	141± 8.25	46.33	Large
Orchard No. 2				
Wealthy	26	184± 5.0	57.44	Large
Winesap	28	157± 5.20	55.27	95 to 1
Winter Banana	19	144± 4.24	45.00	Large
Golden Russett	21	135± 4.47	57.00	Large

*Trunk cross-section areas in square centimeter. September 1940.

TABLE II—GALLIA BEAUTY ON SEEDLING STOCKS PLANTED APRIL 1930, FRANKLIN COUNTY, PENNSYLVANIA (GILLAN BROTHERS ORCHARD)*

Maternal Parents of Seedling Stocks	No. Trees	Mean	Standard Deviation	Odds in Favor of Delicious
Orchard No. 1				
Delicious	25	150±5.28	38.37	——
French crab (Amere-du-Surville)	21	144±6.50	43.05	——
Ben Davis	15	138±6.27	34.76	——
Golden Russett	29	131±3.67	28.77	21 to 1
French crab (Bramtot)	25	120±6.76	49.1	57 to 1
Orchard No. 2				
Siberian crab	7	145±2.50	35.54	——
Gano	16	130±2.50	33.1	215 to 1
Winter Banana	14	127±3.61	24.1	175 to 1
Winesap	19	122±4.25	44.57	585 to 1

*Trunk cross-section areas in square centimeter, September 1940.

and considerably larger than those on Winter Banana and Golden Russett.

In Table II is shown two Gallia Beauty orchards in the same locality. Here, seedlings of Delicious again carry slightly the largest trees but the difference in their favor over trees on French Crab, Ben Davis and Golden Russett is too small to be of much significance.

Seedling stocks of Gano, Winesap and Winter Banana budded to Gallia Beauty have produced trees of virtually the same size in the second orchard shown in Table II. While those on Red Siberian Crab are the largest, only seven are living of the 19 planted. Similar mortality of trees on this stock has been experienced at other orchards. Some of the trees have failed soon after transplanting, while others grew very slowly, giving definite indications of lack of affinity.

The two plantings in Tables III and IV are situated in north-

TABLE III—GALLIA BEAUTY ON SEEDLING STOCKS PLANTED APRIL 1930, ERIE COUNTY, PENNSYLVANIA (M. W. WARD ORCHARD)*

Maternal Parents of Seedling Stocks	No. Trees	Mean	Standard Deviation	Odds in Favor of No. 1
Mixed Domestic No. 1	23	113±4.37	30.41	——
Florence crab	23	99±4.25	29.56	3 to 1
Mixed Domestic No. 2	20	91±4.45	28.77	31 to 1
French crab (Bonne de Freuilles)	28	86±3.55	27.40	Large

*Trunk cross-section areas in square centimeter, September 1940.

TABLE IV—GALLIA BEAUTY ON SEEDLING STOCKS PLANTED APRIL 1930, ERIE COUNTY, PENNSYLVANIA (A. W. FISHER ORCHARD)*

Maternal Parents of Seedling Stocks	No. Trees	Mean	Standard Deviation	Odds in Favor of No. 1
Mixed Domestic No. 1	18	92±3.48	21.26	——
French crab	16	89±3.28	18.84	——
Wealthy	17	83±2.62	15.56	5 to 1
Martha crab	21	82±3.48	23.09	5 to 1
Entz crab	13	68±5.16	26.48	105 to 1

*Trunk cross-section areas in square centimeter, September 1940.

western Pennsylvania near Lake Erie, on sandy loam soil formed by deposits in a glacial lake. This soil is low in humus. Table III shows an orchard of Gallia Beauty on mixed seedlings from two commercial sources, Florence Crab and French Crab. The differences here are not large, except that the trees on French Crab are significantly smaller than those on the first group of mixed seedlings. This seed included Jonathan, Winesap, Rome Beauty and Delicious in unknown proportions according to the Washington seedling grower who furnished it from the supply being used that year for a large commercial crop.

The stocks in the other Gallia Beauty orchard near Lake Erie (Table IV) have induced only minor differences in size except in the case of Entz Crab, which gives indications of dwarfing.

In the comparisons shown here, the emphasis is on relative size. In the case of Gallia Beauty and Rome Beauty, as well as other varieties that grow rather slowly, stocks are needed that will induce the most rapid growth. With varieties inherently more vigorous, the largest trees may not always be the most desirable. Therefore, the results of the present stage of development in these 11-year-old orchards do not afford sufficient basis for a good estimate of the comparative value of the stocks. Delicious seedlings appear to advantage here over French Crab for York Imperial and at least its equal for Gallia Beauty. Wealthy seedlings have produced larger York Imperial trees than the other stocks compared with them, namely, Winesap, Banana and Golden Russett. Mixed seedlings from commercial sources and Wealthy seedlings also rank among the best in size for Gallia Beauty.

Comparative Study of Initial and Subsequent Size of Citrus Cuttings and Budlings

By F. F. Halma, *University of California, Los Angeles, Calif.*

In a previous report (2) on the comparative behavior of citrus cuttings and budlings it was shown that the variability of the two types of trees, while still in the nursery, does not differ significantly. In other words, the data did not support the general assumption that cuttings should be more uniform because the rootstock factor is eliminated.

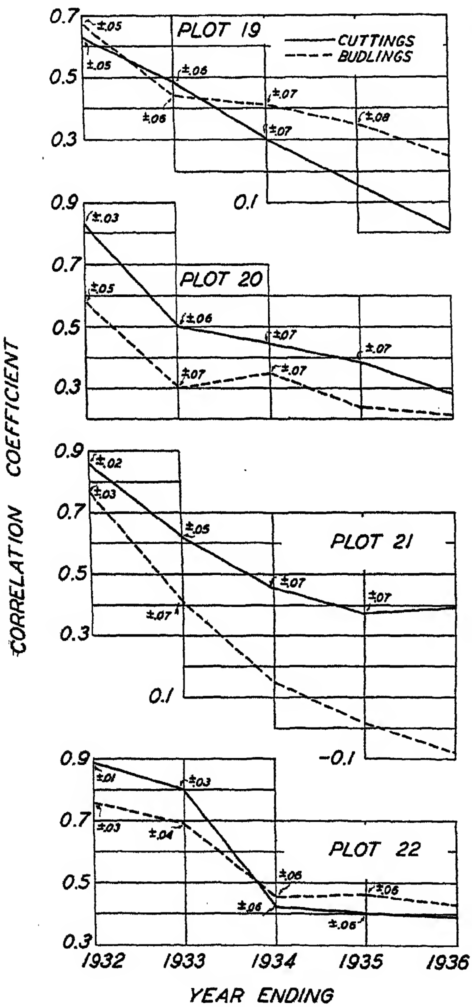

Fig. 1. Eureka lemon cuttings and budlings. Correlation between size at planting in orchard and subsequent years.

In this report on the comparative size (cross-sectional trunk area) of nursery trees and subsequent orchard trees the data indicate that the rootstock, even though of a different species than the scion, is not a significant factor.

Three of the four Eureka lemon plots represented in Fig. 1 were planted in the spring of 1932. The cuttings were then 2 years old and the budlings 1 year old but with a 3-year-old root-system. The fourth plot (number 22) was planted a year later at the request of the grower who believed that 2-year-old buds are more satisfactory. Each plot is in a different commercial orchard but they are less than a half mile apart. The soil is light and rocky, classed as Hanford stony, sandy loam. The rootstock is grapefruit, grown from seed of a single tree. Each grower selected a parent tree from which both the cuttings and the buds were taken. The cuttings were rooted by the method previously

described (1) and they were set out in the same nursery with the rootstock seedlings. The nursery was in charge of an experienced man who also supervised the transplanting to the orchards. All trees were planted bare-root because the rocky nature of the soil made it impossible to ball them. Each plot contains from 68 to 100 of each of cuttings and budlings and they have received the same care which the owner gives to the rest of the orchard.

Although several Navel and Valencia plots were planted most of them are unsuited for statistical study because either the number of trees is too small or the trees suffered a temporary setback during their first 2 years in the orchard. The two plots shown in Fig. 2 contain only from 20 to 34 trees but they are growing in the same orchard which has received uniform care. The soil is classed as Ramona sandy loam. The trees are on sweet orange stock and were planted in 1932. The cuttings were then 3 years old and the budlings were 2-year-buds with a rootsystem 5 years old. It should be mentioned that lemon cuttings grow at a faster rate than orange cuttings to the extent that a 2-year-old lemon is comparable in size to 3-year-old orange. For this reason the orange budlings were kept in the nursery an additional year because most of the cuttings were too small to plant when the budlings were 1-year-old.

All lemon and orange trees were measured in the nursery before they were transplanted and at the end of each growing season thereafter. The cross-sectional trunk area is a reliable growth index for young citrus because the trunk is smooth and cylindrical. In order to avoid complications due to fruit production the calculations are carried only to the end of 1936, when the trees began to bear. The probable error is given where the correlation coefficient is 0.3 or above. In view of the adequate population size, the identity of the rootstock and the similarity of climate and soil the lemon data presented in Fig. 1 are probably as reliable as can be obtained. The steeper downward trend of the cuttings in plot 19 is offset by plot 21 where the situation is reversed. This together with the parallel trend in plots 20 and 22 forces the conclusion that the rootstock was not a factor in the decreasing correlation between ini-

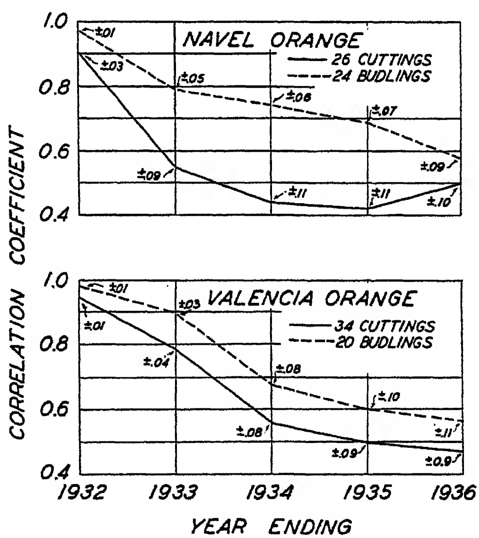

FIG. 2. Navel and Valencia cuttings and budlings. Correlation between size at planting in orchard and subsequent years.

tial and subsequent tree size. The orange data (Fig. 2) support this conclusion although the Navel cuttings and budlings show a wide difference until 1936.

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Failure of Seedlings of Apple, Peach, Pear, and Rose to Respond Favorably to Vitamin B_1[1]

By H. B. TUKEY and K. D. BRASE, *New York State Agricultural Experiment Station, Geneva, N. Y.*

FIRST interest in the use of vitamin B_1 for fruit trees and woody ornamentals, quite naturally is associated with its effect upon the performance of already established plants, as nursery stock and orchard trees. Because of the possibility that any failure of such material to respond to treatment might be due to size and development prior to treatment, as with a 2-year-old orchard tree, tests were made with seedlings, beginning soon after the germination of the seed.

MATERIALS AND METHODS

Seeds of the Delicious apple (*Malus domestica* Van. Es.), the Birch-leaf pear (*Pyrus betulaefolia* Bge.), the Muir peach (*Prunus persica* Batsch.), and the multiflora rose (*Rosa multiflora* Thunb.), were after-ripened and germinated in the greenhouse. The apple and pear seedlings were planted April 27, the rose seedlings May 7, and the peach seedlings May 11.

When the first true leaves had developed, 80 uniform plants were selected from each lot for transplanting to 1-gallon glazed pots, 10 to a pot. Four of the eight pots thus used for each plant material contained greenhouse soil, and four contained unwashed bank sand. Two of these four received vitamin B_1 and two served as checks. In this way, duplicate pots with bank sand and duplicate pots with greenhouse soil received vitamin B_1, and similar duplicate pots received no vitamin B_1, for each plant material used.

Treatment with vitamin B_1 (thiamin chloride) secured from Merck & Company, was begun 4 days after transplanting and continued for 12 weeks thereafter, the material being first dissolved in a small quantity of ethyl alcohol and then diluted with water to a concentration of .01 milligram per liter. Applications of 100 cubic centimeters of this solution, or .001 milligram of vitamin B_1 were made to the pots scheduled for treatment. Check pots received 100 cubic centimeters of water at the same time but without vitamin B_1.

RESULTS

All plants made satisfactory growth, except for the rose seedlings in greenhouse soil, which suffered from damping off and mildew to such a degree as to eliminate them from the test.

No outstanding differences were observed during the season in general growth, color, or development between plants which received vitamin B_1 and those which received none, either in sand or in soil. At the end of the growing season, detailed measurements were made of the entire weight of plants, weight of roots, weight of tops, and

[1]Journal Article No. 429 of the New York State Agricultural Experiment Station.

TABLE I—EFFECT OF VITAMIN B_1 ON APPLE, PEAR, PEACH, AND ROSE SEEDLINGS AS SHOWN BY MEAN TOTAL WEIGHT OF PLANTS, WEIGHT OF ROOTS, AND MEAN SHOOT GROWTH

Material	Check			Vitamin B_1		
	Total Plant (Gms)	Root (Gms)	Total Shoot Growth (Cms)	Total Plant (Gms)	Root (Gms)	Total Shoot Growth (Cms)
	Bank Sand					
Peach (Muir)	6.12	3.58	30.33	4.70	2.95	30.47
Pear (*Pyrus betulaefolia*)	4.13	3.25	11.89	4.48	3.63	12.39*
Apple (Delicious)	3.65	2.97	10.94	3.73	2.76	13.82**
Rose (*Rosa multiflora*)	4.03	2.78	54.35	4.38	2.97	53.55
	Greenhouse Soil					
Peach (Muir)	3.71	2.38	28.69	3.55	2.13	27.43
Pear (*Pyrus betulaefolia*)	4.91	3.65	13.24	3.89	3.08	12.65
Apple (Delicious)	3.74	2.94	10.65	3.43	2.79	10.88

*Difference between means 0.50 centimeters; standard error of difference between means 1.420.
**Difference between means 2.88 centimeters; standard error of difference between means 1.924.

length of shoots. The figures are given in Table I. They were subjected to statistical analysis and show no significant differences between plants receiving vitamin B_1 and those not receiving vitamin B_1, either in greenhouse soil or in bank sand.

The Effect of Diploid and Triploid Seedling Stock on the Growth and Yield of Certain Jonathan Apple Trees[1]

By F. N. Hewetson, *Michigan State College, East Lansing, Mich.*

THE use of seedlings as rootstocks for fruit trees is the common practice in American nurseries. Up until 1930 little attention was given to the parent variety of the seedling as most of them were imported from France as "French Crab". After 1930, it became necessary to grow seedlings in this country on account of plant quarantine regulations. Partly as a consequence of these restrictions, investigations were undertaken in New York and in Iowa to evaluate the seedlings of the various domestic varieties of apples grown in this country. It soon became apparent that in general most of the commercial varieties produced adequate seed, which in turn produced satisfactory seedlings. However, among the varieties tested, a small group produced few seeds which yielded poor slow growing seedlings. At the time no explanation was put forth as to the reason for this poor growth. However, it was not long before a series of articles was published in which it was shown that the lack of vigor of these seedlings was due to their aneuploid constitution, consequent upon the fact that their female parent was of triploid constitution. Nebel (3, 4), Roscoe (5), and others have made cytological studies of a number of apple varieties and have listed their chromosome count. Seedlings of several varieties having a triploid constitution have been grown at East Lansing and elsewhere, and in every case they have produced a poor stand and stunted growth.

Experimental Procedure

In the course of their investigations on size differences in apple trees, Bradford and Joley (1) grew a series of trees on seedlings from diploid and triploid parents. In 1933 these seedlings were budded to Jonathan. The diploid varieties consisted of Northern Spy,

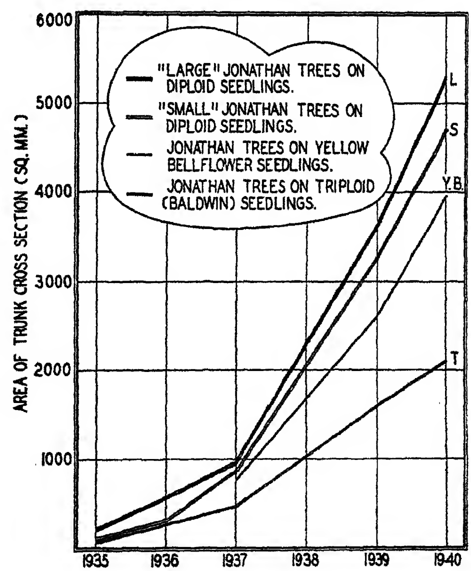

Fig. 1. Average annual growth per tree.

[1]Journal Article No. 505 (n.s.) from the Michigan Agricultural Experiment Station.

Jonathan and Yellow Bellflower, while Baldwin represented the triploid varieties. At the end of the first year of growth, a group of the largest and of the smallest trees on diploid seedlings were planted out in the orchard 10 feet apart. In their report Bradford and Joley (1) grouped the trees on diploid seedlings into "large" and "small", while those on triploid seedlings were all grouped together. For purposes of continuous comparison this grouping will be adhered to as far as possible.

It is the purpose of this paper to continue the story of these trees from 1936, when the writer took over the project, until 1940.

Presentation of Data

Data on the growth of these trees from 1935 to 1940 are presented in Fig. 1 using area of trunk cross section as an indicator of such growth. According to this chart, the original lead of the "large" trees has been maintained, though the difference as of 1940 is not statistically significant. This is in agreement with the findings of Marshall (2) as to the permanence of size differences in orchard plantings. Because of the fact that trees on Yellow Bellflower seedlings were smaller than on all but triploid seedlings, they were segregated and shown separately in the chart. While there was no significant difference in size between these trees and those in the "small" or "large" group they showed differences in yield which will be discussed later. The growth of the trees on Baldwin seedlings is especially interesting in view of the fact that after these trees had been in the orchard for two growing seasons they were only slightly smaller than the "small" trees of the diploid group. However, the following year, *i. e.* 1937, the trees on triploid seedlings showed less annual increase in size than those on diploid seedlings, and subsequent annual growth records only served to accentuate this growth difference. By 1940 this size difference was very noticeable, and it was a simple matter to pick out the small Jonathan/triploid seedling trees in the orchard row.

It was noticeable that during the 1940 growing season these trees on Baldwin seedlings were quite abnormal. Foliage was sparse and small, terminal growth reduced to a few centimeters and fruit bud formation quite prominent. The bark of these trees showed a pronounced orange red tinge in comparison to the normal dark brownish red color of Jonathan trees. Data regarding the yield of these various groups of trees in 1939 and 1940 are presented in Fig. 2. The yields of fruit on the "large" and "small" trees on diploid seedlings and on Baldwin seedlings were practically identical in 1939, though trees on Yellow Bellflower seedlings yielded less than half the fruit produced by trees in the other three groups. In 1940 yields of "large" and "small" trees on diploid seedlings were again very similar and showed a normal increase. A very different situation, however, was evident with trees on Baldwin

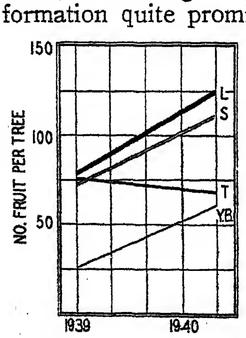

Fig. 2. Yield of fruit per tree.

FIG. 3. A typical Jonathan tree on (A) diploid seedling, (B) triploid seedling stock.

seedlings. Instead of showing any increase in yield, these trees actually showed a decline in yield, with little indication that such a drop would be compensated for in subsequent years on account of the small terminal growth made by these trees. Yield of trees on Yellow Bellflower seedlings showed a normal increase, but was still less than half that produced on the "small trees".

The size of fruit was also affected by the nature of the seedling rootstock. According to data collected in 1940, "large" and "small" trees on diploid seedlings produced fruit averaging 0.24 and 0.21 pounds, respectively. On the other hand, trees on triploid seedlings produced fruit averaging only 0.14 pounds. Fruit on trees growing on Yellow Bellflower seedlings averaged 0.20 pounds.

Because of the fact that the "large" and "small" trees on diploid seedlings were made up of two varieties, it was thought worthwhile to rearrange these groups into varieties rather than size. Comparisons of tree size, however, showed no differences as between trees on Jonathan, Northern Spy or Yellow Bellflower seedlings, but did show a significant difference between trees on Baldwin seedlings as compared to those on the other three varieties of seedlings.

CONCLUSIONS

From the above data it appears that the following conclusions are justified: 1. Jonathan trees on triploid seedlings such as Baldwin are significantly smaller and have yielded less than trees worked on representative diploid seedlings. 2. There was no statistically significant difference in growth and yield between trees on diploid seedlings which were large and those which were small at time of planting. 3. Trees on

Yellow Bellflower seedling produced less than one-half the yield of trees on Jonathan and Northern Spy seedlings, though being comparable in growth to such trees. 4. Size of fruit on "large" and "small" trees on diploid seedlings, and those on Yellow Bellflower seedlings, averaged 0.24, 0.21 and 0.20 pounds, respectively, while those on triploid seedlings averaged only 0.14 pounds.

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Records on a Full Crop Yield of Apple Varieties Topworked on Various Hardy Stocks[1]

By T. J. Maney, *Iowa Agricultural Experiment Station, Ames, Ia.*

YIELD records on large plantings of topworked apple trees under full crop conditions are so few that it seems advisable at this time to present supplemental data on a group of trees, the yearly yields of which were indicated in a previous report (1). Of particular interest is the fact that during the season of 1940 these trees matured a full crop of high quality apples for all varieties. The total crop represented approximately 13,000 picked bushels, out of which were packed about 10,000 bushels.

Table I indicates the yields of a 20-acre orchard set in 1924 to 2-year cut-back Virginia Crab and Hibernal stocks. These trees in the nursery were propagated as root grafts made with long scions and short piece roots of French Crab seedlings. Nine rows of Hibernal and 10 rows of Virginia of 40 trees to the row were planted from east to west across the orchard; therefore each represents 1 acre as the trees were planted on the square, 2 rods apart. The stocks grew through the season of 1924 and were limb budded in August 1925 to various standard and promising crossbred seedling varieties. The stocks were cut back to the buds in the spring of 1926, so that the tops at the

TABLE I—Production of Topworked Varieties

Variety Topworked	1932	1933	1934	1935	1936	1937	1938	1939	1940	1932 to 1939* Total Lbs 40 Trees	1940 Total Lbs 40 Trees	1932 to 1940* Total Lbs 40 Trees
Virginia Crab Stock												
Joan	100	22	8	93	125	693	160	415	495	51,726	20,020	71,746
Willow Twig	25	1	8	20	260	116	255	550	530	42,942	21,004	63,946
Starking	1	38	3	74	8	380	415	355	545	36,874	22,791	59,665
Grimes	20	14	30	82	96	95	395	—	515	19,050	20,464	39,514
Jonathan	39	5	59	217	91	715	394	480	750	65,573	31,194	96,767
Hawkeye	131	98	155	285	213	577	320	975	1135	84,554	45,975	130,529
Norwel	1	36	—	—	78	—	670	—	910	32,098	36,085	68,183
Edgewood	95	27	5	85	55	260	200	242	613	31,199	25,117	56,316
Sharon	—	36	—	—	75	—	595	—	1040	29,418	41,445	70,863
Sharon	—	47	—	—	40	—	615	—	840	26,607	32,080	58,687
						Total =				420,041	296,175	716,216
						Deduct Joan total =				51,726	20,020	71,746
						GRAND TOTAL =				368,315	276,155	644,470
Hibernal Stock												
Willow Twig	—	25	2	—	135	125	335	230	510	27,724	18,698	46,422
Delicious	—	27	18	10	225	138	460	—	995	30,852	40,885	71,737
Grimes	—	23	2	35	132	18	327	—	770	21,148	31,045	52,193
Jonathan	39	52	124	55	210	112	455	6	761	29,871	31,165	61,036
Hawkeye	10	36	45	180	149	597	250	725	895	51,097	36,700	86,897
Norwel	3	46	—	—	63	—	580	—	545	25,462	32,484	47,946
Edgewood	4	27	3	5	55	174	122	60	486	13,573	18,319	31,892
Sharon	—	16	—	—	95	—	495	—	740	15,098	30,063	45,161
Sharon	—	104	—	—	150	—	375	—	795	18,021	31,660	49,681
									Total =	231,946	261,019	492,965

*Inclusive.

[1]Journal Paper No. J-826 of the Iowa Agricultural Experiment Station, Ames, Iowa, Project No. 466.

expiration of the season of 1940 represent 15 years of growth. The bud take was excellent and the subsequent growth has been exceptionally uniform as judged by statistical studies.

The general layout of the orchard which commenced bearing in 1932 is indicated by Table I. It will be noted that Joan is worked only on Virginia Crab and that in computing the grand total for the varieties on Virginia Crab the production of this variety has been deducted. To give a better picture of the regularity of bearing of the different varieties from 1932 to 1940 the yields of single trees, selected at random from the records, are included.

A study of Table I shows that the varieties topworked on Virginia Crab have far out-yielded those on Hibernal. Certain varieties have out-yielded others. This is particularly noticeable for Hawkeye Greening. The varieties which have given high yields have done so largely because of their regularity in bearing. The yields of certain varieties came up mainly because the 1940 crop alone exceeded the total yield from 1932 to 1940. This fact is more pronounced with the Hibernal stock than with the Virginia Crab.

The data given in Table II are of particular interest because they furnish an opportunity to compare the yields of topworked trees with those root grafted and budded on French Crab seedlings.

The stocks were budded in the nursery row in 1928 and set in the orchard in 1930 with 1 year growth on the buds. The data include 10 trees in each lot. The stock designations are explained as follows: O.R., own-rooted; D.W., stock root grafted on French Crab seedlings; 4–7–16, is an open pollinated seedling of Canada Baldwin; 5–2–19, an open pollinated seedling of Patten Greening. All the above combinations were limb budded on the stocks. The Jonathan budded and root grafted on French Crab seedlings are conventional nursery stock. Medium and strong vigor refers to the type of growth which the stocks exhibited in the nursery. Table II indicates the strong influence which the stock has on yielding capacity.

Dudley has made a small tree not only for Jonathan but also for other varieties worked on it. The production on Dudley came up in 1940 but still the trees are of such small stature that they never will compare in production with the trees on the other stock combinations. The Jonathan budded and root grafted on French Crab seedlings, while they are equal in size and uniformity of size to the trees in the other

TABLE II—PRODUCTION OF JONATHAN ON VARIOUS STOCK COMBINATIONS

STOCK	Production (Pounds) 10 Trees			
	1938	1939	1940	Total 1938 to 1940
Jonathan on Hibernal .... O.R.	447	730	2913	4090
Jonathan on Virginia Crab ...... O.R.	495	857	1850	3202
Jonathan on Dudley .... O.R.	30	69	925	1024
Jonathan on 4–7–16 (Strong vigor) O.R.	420	1515	4240	6175
Jonathan on Virginia Crab ...... D.W.	650	235	3245	4130
Jonathan on 5–2–19 (Medium vigor) .... O.R.	150	471	3487	4108
Jonathan—French Crab buds	63	30	2185	2278
Jonathan—French Crab grafts	14	238	1899	2151

combinations, are considerably lower in yielding capacity. Outstanding is the yield of Jonathan on stock 4–7–16 which even has out-yielded the trees on Virginia Crab or Hibernal. The behavior of stock 4–7–16 indicates that much may be gained by the testing of other promising stocks.

The records available from the above demonstrations again emphasize that the stock as well as the variety has a pronounced effect on yields. It is also true that stock effects extend to growth, health and longevity of the tree, and it is reasonable to assume that the stock influence may be greater than that which might be obtained from the application of any other cultural practice. However, we must admit that our knowledge on stocks is still too limited to enable us to give very reliable recommendations as to the use of any given stock. While certain stock varieties seem to be outstanding, yet exact information on any particular stock variety combination can be developed only through long time records on yield, growth, vigor and adaptation.

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The Influence of a Scion Variety on the Resistance of the Roots Against Frost

By W. Filewicz and I. Modlibowska, *Sinoleka Experiment Station, Sinoleka, Poland*

ANTONOVKA in Poland is one of the most resistant varieties. Winter injury to the trunks of this variety has been very seldom reported in the horticultural literature. In Sinoleka orchards, injury was observed only after the very severe winter of 1928–29 on the trees growing on a soil of low fertility in places poorly drained after a heavy crop in 1928. Antonovka, grafted in the top of the trees of tender varieties, was able to increase the resistance of these trees against frost (1). Similar effects were described by Waring and Hilborn in the McIntosh (3).

It is interesting that Antonovka, although the most resistant in the trunk, crotch and branches, has rather a negative influence on the resistance of the roots. In Sinoleka orchards the roots, on which this variety was the scion, froze in a greater degree than those under other varieties. A similar effect was found by Stuart in the Wealthy (2).

In some cases single trees of Antonovka were observed to be injured; in other cases, several trees in one row or in the same plot were effected. In early spring, leaves on these trees showed a chlorotic condition and the apples were of small size. Closer examination of the roots showed that they were damaged by frost in different degrees. The injury was at the time attributed to the tenderness of the roots of injured trees. It was difficult to believe that Antonovka, one of the best known varieties both in Northern Europe and Canada and known especially for its resistance against frost, could bring about such a result.

Yet further proof of this influence was obtained in the Sinoleka nursery in 1938–39. In the autumn of 1936, several thousand apple seedlings of own production — Northern and Central Poland seedlings — were planted in the nursery and several thousand were heeled-in to be planted in the spring. The seeds came from northern and central Poland in the winter of 1935–36. In October 1936, the lowest temperature was —2 degrees C. In November the minimum temperature to the 16th was —1 C to 5.5 degrees C. On the 20th, the temperature fell to —5.9 degrees C and on the 21st it was —11.1 degrees C. There was very little snow in the nursery. During the second and third weeks of January 1937, the minimum temperature fell to —21 degrees C. There was no snow until the 29th and 30th of January. Following this snowless winter, all seedlings froze. Only those which were heeled-in in the autumn survived. To replace the ones frozen, other seedlings were brought from different regions of Poland: Western Poland, Central Poland and Southeastern Poland. The seedlings from Western Poland arrived already severely damaged and were not planted. The rootstocks from Central Poland were much better, but the best originated from Southeastern Poland. Three different groups of seedlings were planted: (a) Seedlings of own production (the seeds from North-

ern and Central Poland); (b) seedlings from Central Poland; and (c) seedlings from Southeastern Poland.

All seedlings were planted in April 1937. They were budded in July 1937 to the following varieties: Antonovka, Transparent de Croncels, Malinova Oberlandzka, Boiken and Kosztela.

In April 1937, in one section of the nursery 22 rows of Malling stocks were planted (each row included about 100 plants) and were budded in the summer with the following varieties: Landsberger r-tte (12 rows), Cox's Orange Pippin (4 rows), Antonovka (1 row), Cortland (1 row), McIntosh (1 row), Golden Delicious (1 row), Delicious (1 row), and Jonathan (1 row).

The budded seedlings and dwarf stocks wintered well and in 1938 reached an average height of 120 to 140 centimeters.

The weather in the autumn of 1938 and the following winter was approximately as follows: In November, the lowest temperature was —2 degrees C. Then the temperature began gradually to fall, and on the 15th of December it reached —6 degrees C. There was absolutely no snow covering in the nursery, and on the 16th of December the temperature suddenly fell to —18 degrees C, falling lower still on December 18, 19 and 20 to —19.3 degrees C.

Observations on the extent and nature of the winter injury to fruit trees in the Sinoleka nursery were made in the spring of 1939. Then the factors of origin of the roots, grade, variety and soil conditions were studied to find the relation of these factors to the resulting injury.

Snagging was done in the nursery in March. In April the difference in colour of the cut surface could readily be seen; a light colour seemed to prove that the roots were healthy, a dark colour indicated the frozen roots, and a medium colour showed that the roots were partially injured.

The influence of the Antonovka trunk on the roots was worse than that of other commercial varieties growing in Sinoleka orchards. Table I shows a comparison between three rows of Transparent de Croncels and three rows of Antonovka budded on the seedlings of the same origin, growing near each other in the same section. The influence of the budded variety on seedlings of the same origin and the same grade growing in the same conditions is generally very similar. The per cent of frozen roots in all the rows of each variety differs but slightly.

TABLE I—EFFECT OF TRANSPARENT DE CRONCELS AND OF ANTONOVKA ON THE HARDINESS OF SEEDLINGS

Frozen Trees		Healthy Trees		Total Number of Trees in Row
Number	Per Cent	Number	Per Cent	
		Transparent de Croncels		
44	46	51	54	95
31	35 42	58	65 58	89
42	45	51	55	93
		Antonovka		
65	69	29	31	94
68	80 75	17	20 25	85
72	75	24	25	96

FIG. 1. Three rows of Antonovka (middle row marked by stick). On the right of these are rows of Croncels. The frozen trees were dug out.

Table II furnishes additional data on the scion influence of Antonovka. If we compare the influence of Antonovka on seedlings of various origin, we see that when grafted with Antonovka only 9 per cent of the seedlings were frozen when seed originated from Northern and Central Poland (Table II — N.C. Poland) while 20 per cent of the seedlings from Central Poland and 75 per cent of the seedlings from Southeastern Poland were frozen.

FIG. 2. Three rows of Croncels (middle row marked by stick). The frozen trees were dug out.

The type of soil in which the seedlings are grown also affects the degree of frost injury; for example, 75 per cent of Southeastern Poland seedlings were frozen in a sandy loam, while 91 per cent were frozen growing in a more sandy soil.

If we compare the influence of Croncels on seedlings of various origin, we see that when grafted with Croncels only 2 per cent of seedlings from N. C. Poland were frozen, while 42 per cent of seedlings from S. E. Poland perished from frost.

The grade of seedlings was also of importance. Grade I seedlings suffered less from frost injury than grade II seedlings: Two per cent of N.C. Poland and 42 per cent of G.E. Poland, Grade I, seedlings were frozen; while 3 per cent of N. C. Poland and 64 per cent of S.E. Poland, Grade II, seedlings were killed by frost.

When grafted with Boiken, 11 per cent of Grade I seedlings from N. C. Poland were frozen; while 18 per cent of those from Central Poland, Grade II, and 51 per cent from S.E. Poland, Grade II, suffered from frost injury and perished.

Dwarf Stocks

The influence of the top-grafted variety on the clonal rootstocks after the snowless winter was observed in the same nursery in April 1939. A difference in colour could be seen in the cut surfaces. As in the case of seedlings, the light colour seemed to prove that the roots were healthy; the dark colour indicated that the roots were frozen.

As we see from the Table III, these dwarf rootstocks also show a different degree of resistance dependent on the variety growing upon them. The freezing of these rootstocks does not depend on the resist-

TABLE II—Effect of the Scion Variety on the Hardiness of Seedlings*

Rootstocks		Frozen		Healthy		Total Number
Origin	Grade	Number	Per Cent	Number	Per Cent	
Antonovka						
Northern and Central Poland	I	60	9	608	91	668
N. C. Poland	II	38	9	380	91	418
Central Poland	II	103	20	417	80	520
S. E. Poland	I	205	75	70	25	275
S. E. Poland	I	3,170	91	309	9	3,479
Boiken						
N. C. Poland	I	66	11	530	89	596
Central Poland	II	86	18	388	82	474
S. E. Poland	II	98	51	95	49	193
Kosztela						
N. C. Poland	I	40	6	576	94	616
Malinova Oberlandzka						
N. C. Poland	I	44	9	424	91	468
Transparent de Croncels						
N. C. Poland	I	10	2	498	98	508
N. C. Poland	II	14	3	409	97	423
S. E. Poland	I	117	42	160	58	277
S. E. Poland	II	841	64	473	36	1,314

*Soil—Sandy loam.

TABLE III—Effect of the Scion Variety on the Hardiness of the Malling IX Rootstock

Number	Variety	Rootstock	Frozen (Per Cent)	Healthy (Per Cent)	Number of Rows
1	Cox's Orange Pippin....	Malling IX	14	86	4
2	Antonovka............	Malling IX	81	19	1
3	Cortland.............	Malling IX	85	15	1
4	McIntosh.............	Malling IX	87	13	1
5	Golden Delicious.......	Malling IX	88	12	1
6	Delicious.............	Malling IX	90	10	1
7	Jonathan..............	Malling IX	91	9	1
8	Landsberger R-tte......	Malling IX	94	6	12

ance of the scion variety, but upon its specific influence on the rootstock. The most tender, Cox's Orange Pippin, had such influence on the dwarfing rootstock, East Malling IX, that only 14 per cent were frozen; while budded with Antonovka, the most resistant of all mentioned varieties, 81 per cent perished from frost.

In conclusion, the above data prove that the freezing of the rootstock depends, not only on its own resistance, but also in a large degree, on the scion variety growing upon it. Microclimatical conditions, and, to a certain extent, the vigour of the rootstocks are of importance.

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Nursery Behavior of Certain European Apple Varieties of Prospective Value as Trunk-Formers

By F. C. Bradford, *U. S. Department of Agriculture, Glenn Dale, Md.*

SOME American nurserymen have long utilized double working in producing trees of certain apple varieties which make poor growth in the nursery; by grafting these varieties on yearling whips of coarser-growing varieties they secure an increase in the percentages of trees meeting standard requirements as to caliper and, in some measure, as to height. For many years some fruit growers in regions of particularly cold winters, notably in Iowa, have resorted to double-working in the orchard as a means of securing greater hardiness in trunk and crotches, usually the most vulnerable portions of an apple tree. In comparatively recent years some double working has been done in the nursery as a means of forestalling injury from the organism producing collar rot, to which Grimes Golden is notably susceptible. Since the number of varieties suitable for use as interstocks is limited, and some of these have been shown experimentally to have adverse effects on certain varieties worked on them, though they affect others beneficially, additions to the list of potential interstocks are desirable. The ultimate test of interstocks, or "trunk-formers", must obviously be made in the orchard, but the preliminary sorting of candidates for the orchard tests should be done in the nursery, since a variety which does not make at least average growth in the nursery will be handled reluctantly by nurserymen and cannot be topworked readily at the most advantageous time, in the nursery or in the orchard.

The present paper records the first year's growth from bud, in the nursery of the Division of Plant Exploration and Introduction, at Glenn Dale, Maryland, of certain foreign varieties of apple, which were included in the test either because they are used in European nurseries as trunk-formers or because they have been reported to be highly resistant to winter cold or in a few cases because observation suggested desirability of their trial. Still other varieties are being tested in similar manner. Usefulness as trunk-formers in Europe does not guarantee similar usefulness under American conditions, partly because of climatic differences, but more particularly because the method employed in double-working in Europe differs widely from that suited to American conditions and because selection of trunk-formers in Europe is made with reference to resistance to a canker not prevalent in America and without reference to resistance to fire-blight, which is not prevalent in Europe.

In a few cases authenticity of the introduced material has been definitely established; in many cases this has not been possible. For this reason the Plant Introduction numbers, as well as the variety names, are listed.

The varieties used in these tests were represented, in most cases, by 50 to 60 trees. In two years these were budded in systematic rotation; in one year they were budded in randomized plots of five

TABLE I—Growth Made by Virginia Crab as Yearling Whip in 1938, 1939 and 1940

Year	Trees (No)	Mean Height of Whip (Cm)	Mean Diameter at 5 Cm From Bud (Mm)	Trees Graftable at 76 Cm (Per Cent)
1938	67	141.9	13.0	89.6
1939	58	132.0	12.8	89.8
1940	53	112.9	10.1	52.8

trees each, arranged in three blocks. Aside from prompt removal of secondary shoots, the trees received no special care. They have been infested rather consistently with apple twig borer, which seems to work impartially so far as varieties are concerned, and by leaf-hoppers, whose effects are shown much more by some varieties than by others. In one year fire-blight was present.

Virginia Crab has been grown each year as a representative American trunk-former, to serve as a standard by which other varieties are measured and through which varieties grown in different years may be compared. Its growth in each of the three years covered by this report is set forth in Table I, in absolute measurements. Growth of the other varieties, expressed in percentages of that of Virginia Crab for

TABLE II—Seedling Diameter After Budding and Height of Yearling Produced by Certain Apple Varieties (in Percentage of Growth Made by Virginia Crab in the Same Season)

P. I. Number	Variety	Origin	Year of Test	Trees (No.)	Seedling Diameter (Per Cent of V.C.)	Height of Whip (Per Cent of V.C.)
89799	Coulon	Germany	1939	56	95.3	122.7
103442	Antonovka	U.S.S.R.	1939	58	100.0	120.5
125565	Noir de Vitry	France	1939	58	98.1	112.9
104995	Pippin Shafran	U.S.S.R.	1939	24	100.9	106.8
......	Dudley	U.S.A.	1940	61	95.1	105.9
90524	Bellefleur Kitaika	U.S.S.R.	1939	58	97.2	104.5
123993	Linda	Canada	1940	60	104.9	103.1
104996	Red Standard	U.S.S.R.	1940	59	99.0	99.1
102561	Transparent de Croncels	France	1940	55	101.0	96.6
105405	Virginischer Rosenapfel	Holland?	1939	59	101.9	96.2
125566	Surpasse Fréquin	France	1940	61	103.9	95.7
105279	White Alphington	England	1939	57	96.2	93.2
125759	Landsberger Renette	Germany	1940	56	99.0	92.0
107224	Komsomoletz	U.S.S.R.	1940	63	100.0	91.2
104999	Yakhontowoye	U.S.S.R.	1940	58	100.0	90.7
105278	Bulmer's Norman	England	1939	60	100.9	90.2
122620	Pres. Descours-Desacres	France	1938	62	104.2	90.2
122618	Gros bois de Doudeville	France	1938	64	100.0	89.8
132286	Omont (Faux Cailleul)	France	1940	46	105.9	88.4
107197	Antonovka Shafran	U.S.S.R.	1939	43	98.1	87.9
113472	Anis	U.S.S.R.?	1939	52	98.1	87.1
107229	Kulon Kitaika	U.S.S.R.	1939	57	95.3	86.4
122616	Doux-amer	France	1939	57	101.9	85.6
113474	Hibernal	U.S.S.R.	1939	58	98.1	81.8
107246	Severnii Bujbon	U.S.S.R.	1940	53	104.9	80.7
125765	Roter Trierischer Weinapfel	Germany	1940	49	102.9	80.4
107253	Tayezhnoie	U.S.S.R	1939	57	100.0	78.0
125731	Reichelsheimer Weinapfel	Germany	1940	51	107.0	75.2
105389	Grüne Fürstenapfel	Germany	1939	52	99.1	74.2
123736	Long bois	France	1939	59	96.2	74.2
122621	Souvenir Du Marais	France	1938	63	102.1	73.5
122617	Fertile de Doué	France	1938	24	94.8	72.9
113828	Manitof	Canada	1939	60	101.9	72.7
107248	Shafran Osenii	U.S.S.R.	1940	52	101.0	71.6
107203	Borsdorf Kitaika	U.S.S.R.	1940	49	96.0	66.2
104796	Harberts Renette	Germany	1938	35	101.0	55.0

TABLE III—VARIETIES COMPARED AS TO PERCENTAGES OF TREES LARGE ENOUGH AT 76 CM FOR GRAFTING AND AS TO BASAL DIAMETER

Variety	Per Cent Graftable (Per Cent of V. C.)	Diameter at 5 Cm (Per Cent of V. C.)	Per Cent Graftable (Rank)	Diameter at 5 Cm (Rank)	Length of Whip (Rank)
Surpasse Fréquin	161.4	122.8	1	1	11
Dudley	105.5	92.1	2	16	5
Gros bois de Doudeville	104.7	104.8	3	5	18
Noir de Vitry	103.7	104.7	4	6	3
Coulon	103.5	119.5	5	2	1
Pres. Descours-Desacres	100.8	98.8	6	11	17
Virginia Crab	100.0	100.0	7	9	7
Antonovka	99.8	111.7	8	3	2
Transparent de Croncels	99.8	93.6	8	15	10
Linda	96.8	91.1	10	19	7
Bulmer's Norman	96.5	100.0	11	9	17
Souvenir Du Marais	93.9	102.2	12	7	32
Red Standard	93.2	95.0	13	13	9
Kulon Kitaika	91.9	106.3	14	4	23
White Alphington	76.2	84.4	15	29	13
Bellflower Kitaika	74.8	100.7	16	8	6
Pippin Shafran	72.6	100.0	17	9	4
Yakhontowoye	71.8	86.1	18	27	16
Anis	66.5	89.8	19	21	22
Virginischer Rosenapfel	66.0	86.7	20	26	11
Antonovka Shafran	64.8	85.2	21	28	21
Landsberger Renette	64.2	83.2	22	32	14
Doux-amer	62.5	88.3	23	23	24
Omont (Faux Cailleul)	61.7	92.1	24	17	20
Manitof	61.2	89.8	25	22	34
Tayezhnoie	56.7	93.8	26	14	28
Fertile de Doué	55.8	83.3	27	31	33
Komsomoletz	54.2	82.2	28	33	15
Roter Trierischer Weinapfel	50.2	81.2	29	34	27
Hibernal	48.0	92.2	30	16	25
Severnii Bujbon	39.4	90.1	31	20	26
Grüne Fürstenapfel	34.3	88.3	32	23	30
Long bois	32.1	71.9	33	36	31
Reichelsheimer Weinapfel	25.9	84.2	34	30	29
Harberts Renette	16.0	66.4	35	37	37
Borsdorf Kitaika	11.6	87.1	36	25	36
Shafran Osenii	11.0	72.3	37	35	35

the same year, is presented in Tables II and III. Statistical constants are not presented, but their import may be summarized in the statement that differences of 5 per cent are not consistently significant, but those of 10 per cent are almost invariably significant. Likewise the relative rankings indicated in Table III are in most cases to be regarded as approximate rather than absolute.

The range in mean diameters of seedlings measured in the autumn after the buds had been set, reported in Table II, is small and so distributed as to indicate that differences in size of seedling budded did not materially affect the subsequent growths from the buds. The heights of the whips shown in this table, therefore, seem to present a reliable comparison of the initial growth possibilities of these varieties under the existing conditions. As one-year whips, only three varieties were notably taller than Vrginia Crab, and one of these, Antonovka, has long been known in this country. On the other hand, a considerable number are close enough to Virginia Crab for practical purposes, so far as grading of nursery stock is concerned. Of the other varieties in the test which have been more or less used as trunk-formers in America, to wit: Dudley, Hibernal and Anis, only the first has made high standing in length of whip.

Top-working in the nursery is done usually by grafting on yearling

whips. To ensure freedom from the collar rot organism, the minimum height at which this may be done has been stated as 30 inches. To ensure growth from the scion adequate to formation of a satisfactory head in one year, scions of at least 6 millimeters diameter should be used. These two considerations led to the establishment, for the purposes of this study, of a standard of at least 6 millimeters diameter at 76 centimeters as the criterion determining whether a yearling is "graftable".

The arrangement of varieties in descending order of percentages of graftable trees, as shown in Table III, presents considerable difference from the placement according to height. Surpasse Fréquin, only eleventh in height, produced a high percentage of graftable trees because of the unusual thickness of its whip, which is conspicuous in the nursery. Dudley, slender at the base of the whip, is tall enough and tapers little enough to secure high ranking in this respect. Use of a fixed standard (as 6 millimeters) for comparing performances of different years introduces certain inaccuracies for which allowance should be made. In 1939, for example, when 89.8 per cent of the Virginia Crab trees were of graftable size, a variety producing 100 per cent of graftable trees could exceed Virginia Crab by only 10 per cent, since diameters above 6 millimeters count no more in tabulation than those of this figure. In a year in which the percentage of graftable Virginia Crab trees is lower, the margin might be greater. Specifically, had Coulon or Noir de Vitry been grown in 1940 and Surpasse Fréquin in 1939, their relative positions in "per cent graftable" might have been reversed. This appears to be the only case in which there is uncertainty; manifestly they were all equal to or better than Virginia Crab in this respect and obviously the varieties rating below Virginia Crab are comparable.

Caliper close above the bud, one of the standards by which trees are graded for sale, does not correspond in all cases with diameter at the higher point on the whip. Dudley, for example, outstanding for diameter at 76 centimeters, is only average in diameter at 5 centimeters. Kulon Kitaika, on the other hand, rather well down the list in percentage graftable, is among the leaders in diameter above the bud.

The comparisons presented here justify nothing more than selection for further trial in cases where topworking in the nursery is the point of chief interest. Topworking to secure cold resistance in trunk and crotches must be done on older trees, and the varietal relationships existing at the end of the first year in the nursery change materially in some cases during the second year.

Some varietal peculiarities deserve mention. Surpasse Fréquin is unusual for its straight, thick whips; beyond this little information is available concerning this variety, whose use in France as a trunk-former seems not to be extensive. Souvenir Du Marais has shown tenderness to cold in three of the four winters through which it has stood in the nursery at Glenn Dale. Indications of blight resistance are available only on the trees grown as whips in 1939; these were subject to severe attack in 1940, their second year. The attack started in blossom infection on the whips of Tayezhnoie, most of which blos-

somed from lateral buds. Since the Tayezhnoie trees were scattered systematically through the block, a thorough "seeding" was provided. Weather conditions for some time favored blight development, and even Virginia Crab, regarded as virtually immune, developed important infections on two trees. Losses were naturally greatest in Tayezhnoie, involving 32 per cent of the trees; this was followed by Douxamer with 25 per cent, Noir de Vitry with 22 per cent and Kulon Kitaika with 15 per cent. Hibernal and Antonovka were affected alike (12 per cent). Infestation was very light in Grüne Fürstenapfel (4 per cent) and in Bulmer's Norman (2 per cent). The only varieties to escape entirely were White Alphington and Coulon, but a mature tree of the latter variety in the orchard was heavily attacked through its blossoms. Closeness to centers of infection seemed not to determine its amount; the White Alphington trees were closer in the rows to the Tayezhnoie trees than those of most of the varieties that suffered heavily. The remaining varieties in this group developed infections in from seven to 10 per cent of the trees.

Clonal Selection of Grapefruit With Respect to Yield

By W. H. Friend and S. H. Yarnell, *Texas Agricultural Experiment Station, A. and M. College of Texas, College Station, Tex.*

THE possibility of increasing the yielding capacity of a clonal variety through bud selection holds both practical and theoretical interest. The grower wants increased yield. If a more productive strain of an asexually propagated variety is discovered, the propagating material will have considerably increased value over similar material from normal plants of the variety. If the likelihood of such a discovery is slight or non-existent, the justification for growers paying a premium for "superior" strains, while varying with the kind of crop, would at best be questionable. In the case of citrus, because of the excellent work of Shamel and his associates, there is little or no excuse for the propagation of strains of less than normal productive capacity.

A number of workers have tried to establish differences in yielding capacity of strains through bud selection. Results up to the early twenties have been reviewed by Sax and Gowen (3) who conclude that the evidence is against a change of productive capacity through bud mutation. They suggest that the reduced yield of certain apple and potato selections was due to a diseased condition transmitted in propagation. Shamel, Pomeroy, and Caryl (4) have since presented evidence to show that the yield of the Washington Navel orange can be materially reduced through bud selection. Totaling their figures, 60 trees propagated from 15 types of bud mutation known to have lower yields than comparable normal trees gave an average total of 735 fruits per tree during a period of 8 years. Some 38 trees propagated from normal Washington Navel and Thompson strains produced on an average 1,525 fruits over an equal period of time. All trees were grown under comparable conditions. Several mutations, such as Golden Buckeye and Golden Nuggett, that produced only slightly less than normal are included in this total. While this is strong evidence that yield can be reduced through bud mutation, as might be expected on theoretical grounds, it throws no light on the possibility of improving the yielding capacity of a clonal variety by means of bud selection.

Variations in yield due to rootstock, soil and other environmental conditions prevent the determination of a satisfactory index of productive capacity for a variety valid for all conditions. If a higher yielding bud mutation occurred and were recognized, it should be possible to show a significant difference between yields of trees propagated from it and those propagated from normal wood, when grown under comparable conditions.

Material and Methods

As with other workers our plan has been to propagate trees, securing the budwood from orchard trees differing in individual yield records. A difference in yield between clonal lines of two selections would be taken as indicating a genetic difference with respect to yield for the

original trees selected. Lack of a significant difference in the progeny would indicate that the trees from which budwood was selected varied in yield because of environmental factors. The selections were based on a 5-year average in terms of pounds of fruit per tree. Most were of Marsh grapefruit trees, although five were selections of Thompson, which is a pink fleshed bud variation of Marsh. All were budded on sour orange seedlings, commonly used commercially, except two of the Thompson selections, which were put on Cleopatra mandarin roots. Four of the selections 29–3, 39–9, 4–1 and 4–12 came from a commercial grove in Arizona and were set in the orchard in 1932. The rest were made on Texas Substation No. 15 in the Lower Rio Grande Valley, where the clonal progeny tests were carried out. The Marsh trees were set in 1929, the Thompson in 1931. Budlings from comparable selections were planted in adjacent rows and given the usual care. Two of the paired selections of Marsh trees were grown in a single block with budlings from trees of known production between and on one side of the paired selections. Clonal progeny of a third selection was grown adjacent to a third pair of selections of Marsh, and a third selection of Thompson was grown adjacent to the pair of Thompson selections on sour orange roots. The hurricane of September 1933 severely damaged some of the trees. In the few cases where trees did not recover satisfactorily they and the corresponding trees in adjacent rows were excluded from the results.

An analysis of variance based on annual individual tree yields was made for all paired progeny and also for the two blocks of three selections and for the single block of six selections mentioned above. F was determined by dividing the variance for selection by the variance for the interaction of years and replications plus the variance for the triple interaction of selections, years and replications (the residual mean square). Each budling tree of a selection was considered as a replicate. The 5 per cent point for the distribution of F was taken from a table published by Snedecor (5). Mr. Homer T. Blackhurst assisted with the calculations.

Results and Discussion

The results are summarized in Table I. Lack of space prevents the presentation of individual tree records for each season. The first nine selections are of Marsh trees growing in the station orchard; the next four represent Marsh trees in an Arizona grove; and the last five are of Thompson trees on the Lower Valley station, the first three on sour orange, the last two on Cleopatra mandarin rootstocks. The column heading "n" refers to the number of budling trees propagated from each selection.

Lack of significance for that part of the variance that may be ascribed to the source of budwood is indicated by a value of F below that of the 5 per cent point for all selections except the Thompson selections (6–7, 6–8 and 6–9). When all three selections are considered and likewise when only 6–7 and 6–8 are compared the value for F lies between the 1 and the 5 per cent points. Inspection of columns two and three permits a comparison between the 5-year average production

TABLE I—AVERAGE YIELDS OF SELECTIONS AND THEIR CLONAL PROGENY (POUNDS PER TREE) WITH THE VARIANCE OF SELECTIONS AS INDICATED

Selection		Average Yield of Budlings					Variance		F	5 Per Cent Point
No.	Yield	1937 to 1939	1937	1938	1939	n	Based On	Mean Square		
37–6	406	603.7	468.0	937.4	405.7	7	All three	29,388.21	1.55	3.26
37–5	454	579.0	507.9	895.7	333.3	7	37–5; 33–3	56,760.38	2.40	4.26
33–3	555	652.5	554.4	957.1	445.9	7	——	——	——	——
30–3	488	419.1	399.9	462.5	394.9	10	All six	24,290.58	2.14	2.30
30–4	568	379.7	410.1	368.0	361.1	10	30–4; 31–6	7,282.02	0.81	4.11
31–6	460	357.7	348.6	396.0	328.5	10	31–9; 31–10	654.31	0.05	4.11
31–8	444	335.8	340.2	393.8	373.5	10	——	——	——	——
31–9	236	362.9	364.6	406.2	318.0	10	——	——	——	——
31–10	492	356.4	374.6	377.8	316.7	10	——	——	——	——
39–9	644	403.3	422.5	451.9	335.6	10	Both	1,000.42	0.04	4.11
29–3	324	411.5	405.6	477.5	351.4	10	——	——	——	——
4–1	325	341.7	335.1	351.0	336.4	11	Both	13,302.56	0.56	4.08
4–12	240	369.2	357.0	418.2	332.5	11	——	——	——	——
6–9	804	449.6	371.7	366.0	611.2	10	All three	39,616.85	4.71	3.17
6–8	815	378.4	317.5	296.1	521.7	10	6–8; 6–7	34,896.81	4.53	4.11
6–7	907	426.7	366.6	356.0	557.4	10	——	——	——	——
6–11	899	402.9	336.2	357.8	514.6	9	Both	15,402.67	1.56	4.15
6–12	944	369.1	311.7	324.4	471.1	9	——	——	——	——

of the tree from which the budwood was secured and the average production of all of the budling trees over a 3-year period. In the case of the Thompson selections referred to above, trees from the lowest producing selection gave, on the average, the best yield of the three. If the difference between the other two is considered to be significant, it can hardly be said that Thompson tree 6–7 represents a bud mutation for improved yield over the normal yielding capacity for the variety, since trees budded from the lowest producer, 6–9, out-yielded the clonal progeny of 6–7 under comparable conditions.

If we consider only paired selections whose budling trees grew in adjacent rows, we find that in four of the seven pairs the budling trees from the low selections out-yielded those from the high selections. The 67 trees budded from the high producers averaged 407.4 pounds per tree annually. An equal number of trees from the low producers averaged 400.7 pounds per tree annually. These last two figures were obtained by dividing the total weight of fruit, slightly over 40 tons in each case, by the number of trees in each group multiplied by three.

The data indicate clearly that the yield differences shown by the individual records of the "parent" trees selected were due entirely to environmental factors rather than to one or more genetic mutations influencing the yield.

In concluding that there is no genetic effect tending to increase the productive capacity of any of the grapefruit trees selected for the test over the normal yield for the variety, it is realized that it is impossible to rule out all chance of such a bud mutation sometime occurring. Marsh tree 33–3 is one of the best producers of that variety on the

station. Arizona budwood of the best selections under test was at one time sold to Texas nurseries as a "superior" strain of the variety. As far as the relatively small number of selections for high production permit, they would seem to be a fair sample of superiority as determined by the individual tree record. Several of the selections for low production could be said to represent "inferior" strains by the same criterion, yet budwood from each type was equally valuable as judged by the clonal progeny test. These results would, then, indicate that where the nurseryman takes care to avoid the "shade tree" and other obviously unproductive and otherwise undesirable types of mutations, securing his budwood from what appear to be normal trees, variations in productivity as they normally occur in the orchard are unlikely to reduce the potential productive capacity of his nursery trees. Further, if he limits his budwood source to trees of known high production he is not justified in advertising his trees as representing a superior strain and charging growers a premium on this basis.

These results would seem to be in line with the observation frequently made with genetic material, that a mutation is more apt to be harmful than beneficial to an organism. It is reasonable to suppose that a biologic character as complex as yield would be unlikely to be improved by a gene mutation. Such a supposition is, of course, equally applicable to all crop plants. In general this seems to hold true. As an apparent exception, both Anderson and Richardson (1) and Miller (2) have isolated strains of the sweet potato that have given evidence of being more productive than normal for the variety. The sweet potato, like citrus, has numerous visible bud mutations. Miller's productive selection, called Louisiana Unit One, has been grown in comparison with other selections for several seasons by R. E. Wright at the Texas Agricultural Experiment Station's Sweet Potato Laboratory at Gilmer, Texas. Unpublished data secured by Wright discloses an improved yield over the common stock not only for Louisiana Unit One but also for four additional selections, two of which were not saved primarily because of high yield. The relative frequency of the appearance of these high producing strains together with the high rate of bud mutation in this crop suggest the possibility that the relatively poor stocks of most growers of sweet potatoes are the result of the accumulation of bud mutations that reduce the yield, and that these improved strains may represent the original normal productive capacity of the variety. Such an explanation, if true, would increase the chance of finding high yielding selections of the sweet potato, and would support the idea that bud mutations tending to increase the yield of a variety are so infrequent as to be negligible in the improvement of clonal varieties through selection.

Summary

A comparison of the budling progeny of seven pairs of selections for high and low yield in two related varieties of grapefruit gave approximately equal yields for both types of selection. It is concluded that (a) the use of budwood from normally vigorous trees of relatively low productivity is unlikely to be reflected in the yielding capacity of

the resulting trees; and (b) strains of superior productive capacity are not to be expected through the exclusive use of budwood from trees known for their high yields.

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Adventitious Buds in Citrus

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'NVESTIGATORS have on various occasions studied the induction . of adventitious buds in plants, and, as a result the ability of some lant species to regenerate this type of organ has long been recognized. 'he subject, however, has been recently linked with the hormone ıeory and its control of growth and cell division which is frequently iscussed in horticultural and botanical literature.

The study reported in this paper was conducted in the spring of 940 in an effort to determine the ability of some of the common citrus pecies to regenerate adventitious buds; a question of some interest to ıe horticulturist, although at the moment of no commercial value.

Survey of Literature

No comprehensive review of literature will be attempted in conection with this report. Only a few of the recent papers dealing with dventitious buds will be mentioned. Simon (10) working with cut:ngs of *Populus nigra* found that numerous adventitious buds formed rom the apical callus. Greenleaf (3) reported bud regeneration in isbudded plants of Nicotiana with the help of low concentration of ıdoleacetic acid applied to the cut surface. Jorgensen (6) found that ecapitated plants of *Solanum nigrum* regenerated adventitious shoots fter the axillary buds had been removed. Povolochko (9) reported imilar results with "Nicotiana" adding that the number of adven-itious buds increased when orchid pollen was applied to the cut sur-ace. Hachaturov (4) states that bud regeneration of disbudded Nico-iana occurred best between the first and the fifth leaf. Bouillenne (1) nd others believe that indoleacetic acid does not inhibit adventitious ud formation. Link and Eggers (7) found that adventitious shoots ould arise from the hypocotyls of flax seedlings, decapitated below he cotyledon leaves. Zimmerman and Hitchcock (11) reported that Althea cuttings produced numerous adventitious shoots along the dis-udded stem from both the callus and bark, while the cuttings of Populus and Elaeagnus produced adventitious buds only at the apical ut surface and the scars where buds were removed. Mendel (8) eported the formation of adventitious buds on the hypocotyl of a lecapitated seedling of *Annona muricata* considering this the first nstance of its kind yet reported for a woody plant. Chandler (2) p. 253, states that, "with most kinds, shoots may grow from adventitious uds in the roots; but with nearly all, if not all, of our deciduous fruit rees, shoots seldom, if ever, grow from adventitious buds in tissues ıbove ground". No reference to adventitious buds in citrus has been ound in the literature. However, Halma (5) in 1918 observed the levelopment of adventitious buds from intact bark and apical callus of lisbudded citron cuttings placed in a moist chamber, Fig. 1.

Materials and Methods

The principal material used in the experiments consisted of 3-year-

old nursery seedlings, of sour orange, sweet orange, lemon, and rough lemon, which were disbudded either by removing the buds with a knife or burning them with an electrical wood burner. Twelve seedlings of each were treated, except the lemon of which only one seedling was available. In addition an effort was made to determine the effect of varying the amount of bark removed with the bud, the method of removal, the number of buds left on the seedling, and the use of a "tree seal" material to cover the wound surface. Most of the seedlings selected contained only one main stem. Laterals were removed to limit the number of buds to a reasonable number. The terminal portions of these seedlings were removed because of the difficulty of disbudding this part effectively without girdling the stem. Instead of disbudding the basal portion of the stem all the buds that sprouted in this region were systematically rubbed off by hand as soon as they appeared. Some

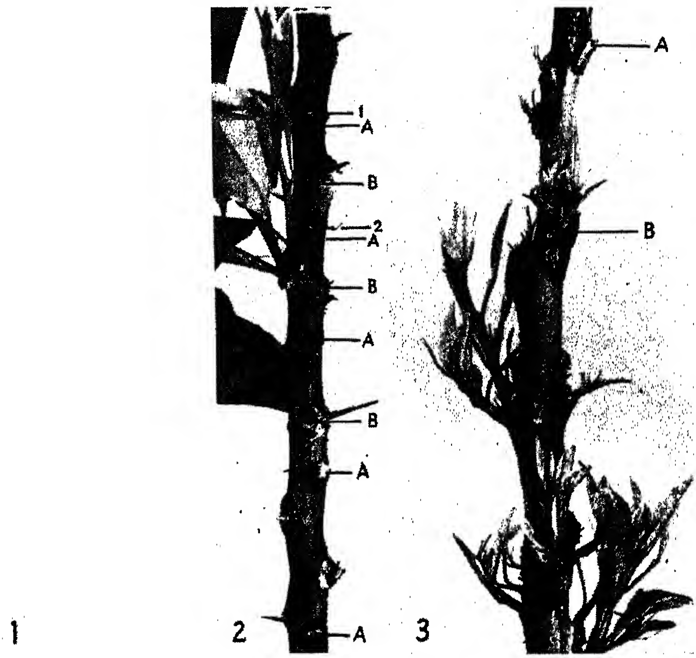

FIG. 1. Adventitious shoots on a citron cutting which was partially disbudded and placed in a horizontal position in a moist chamber. Photograph by Halma, 1919.

FIG. 2. Adventitious buds from internodal scars in sour orange seedlings. (A) Internodal scars (scars made in the bark without any relation to the original buds); (B) original buds scars, 1 and 2 adventitious buds growing from internodal scars.

FIG. 3. Adventitious buds in sour oranges. (A) Developing adventitious bud; (B) adventitious shoots.

of the sour orange seedlings were wounded in the internodes between the buds as indicated in Fig. 2.

To determine the capacity of young seedlings to produce adventitious buds when treated with hormone (3 indoleacetic acid), 25 sweet orange seeds were planted in each of 20 6-inch flower pots and kept under glass house conditions.

When the seedlings were 4 weeks old they were selected for treatment on the basis of vigor and uniformity, accordingly the number of treated plants in each pot varied. The average height of the selected plants was about 2.5 inches. The treatment consisted of decapitating the plant about 1 inch below the oldest leaf, thus removing all buds normally differentiated and leaving only a bare piece of the stem to represent each seedling. Different materials were applied to the cut surface as indicated in Table I.

Results and Discussion

For the sake of clarity the results of these investigations will be discussed under separate headings.

Adventitious Buds on 3-Year-Old Seedlings:—In general, complete disbudding of the seedlings resulted in the production of numerous adventitious buds in the three major varieties of citrus investigated. Within a period of 5 to 6 weeks from the time of treatment, the disbudded seedlings in which the wound surface was covered with a "tree seal" material of asphaltic base, started to develop adventitious buds from the callus tissue which by that time almost covered the whole wound surface. More than 60 per cent of the scars initiated adventitious buds and in most of them more than six shoots originated from a single scar. In seedlings in which the wounds were left uncovered, the surface dried, and callusing was rather slow. Adventitious buds, however, regenerated from the callus tissue, developing on the edges of the bark wounds approximately 2 months after disbudding. Furthermore uncovered scars produced fewer adventitious buds and not more than three shoots came from any single scar, presumably because the adventitious shoots that did develop grew very fast resulting in the formation of leaves, lateral branches and buds which in turn may have inhibited the regeneration of adventitious buds on the other scars. This explanation seems to be substantiated by the fact that in the partially disbudded seedlings both the asphaltum painted and exposed scars regenerated few, or no adventitious buds, while the original buds

TABLE I—Adventitious Buds Produced by Decapitated Sweet Orange Seedlings

Number Pots	Number Seedlings Tested	Treatment	Seedlings Regenerating Adventitious Buds	
			Number	Percentage
4	53	0.1 per cent aux	31	58.5
4	61	0.5 per cent aux	31	50.8
4	57	Control no treatment	32	56.1
4	51	Tree seal	46	90.2
2	27	Pure lanolin	15	55.6

left, grew quickly to vigorous shoots. Removal of such shoots and the rubbing off of all normal buds which subsequently started, in some instances induced the growth of adventitious buds from the scar tissue. Removal of the buds with an electric wood burner proved to be an easier method, but callusing and bud generation was slow, and there was no pronounced difference between scars covered with "tree seal" and exposed ones. The delay in callusing apparently was due to the complete killing of the cambium in the treated area and the injury to the adjacent cambium tissue. In the case of knife disbudding the paint protected exposed parts of the cambium which remained attached to the wound surface and thus permitted more rapid callusing and bud regeneration.

In the series of seedlings where the buds were removed with a small piece of bark (Fig. 4) and as a result most of the leaves were left attached, callusing and bud regeneration were more rapid than where the wounds were large and the leaves were absent.

That adventitious buds may develop in the callus produced at internodal scars is indicated by Fig. 2. On no occasion, however, were buds seen to regenerate from the apical cut end or from intact bark, although Halma (4) did observe regeneration in both positions in a humid atmosphere.

We are not able to make any definite statement regarding the capacity of the different varieties tested to regenerate buds because of the difficulty of obtaining comparable material. Sour orange seedlings, however, seemed to be more capable of producing adventitious buds than either sweet orange or rough lemon. Sweet orange produced fewer adventitious buds than any of the others; this however, may have been due to the fact that they were the least vigorous. The only lemon seedling investigated produced numerous adventitious buds and seemed to be equal in capacity to the sour orange.

Fig. 4. Adventitious buds in rough lemon. (A) Uncovered scar showing one of the methods of disbudding in which the buds were removed with a small piece of the bark and the leaves left attached.

Adventitious Buds in Decapitated Young Seedlings:—The results presented in Table I indicate that decapitated young

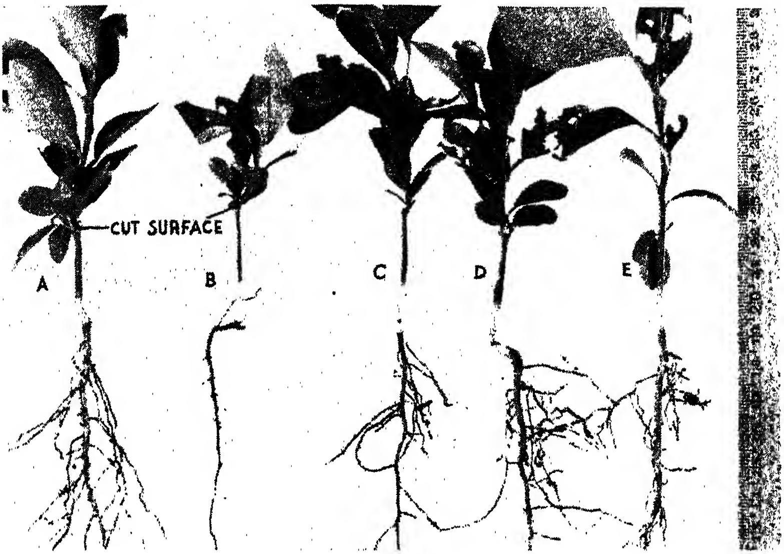

FIG. 5. Adventitious shoots produced by decapitated sweet orange seedlings. (A) Tree seal; (B) 0.5 per cent indoleacetic acid; (C) 0.1 per cent indoleacetic acid; (D) pure lanolin, and (E) control.

sweet orange seedlings are capable of producing adventitious buds from the callus tissue at the apical end, usually from 2 to 4, Fig. 5. Root inducing indoleacetic acid did not increase the number of adventitious buds, in fact the higher concentration of auxin (0.5 per cent) reduced it. Asphaltum "tree seal" material markedly increased the percentage of seedlings which regenerated shoots. It also reduced the average time required for regeneration by about 1 week.

Conclusions

Disbudded citrus seedlings possess the capacity of regenerating adventitious buds from the callus tissue that covers the wound surface. "Tree seal" asphaltum paint seems to stimulate the regeneration of both callus tissue and adventitious buds. Indoleacetic acid did not stimulate the development of adventitious buds. In this investigation adventitious buds developed only from scar tissues. Sour orange and lemon seedlings appear to possess the highest capacity for regeneration amongst the varieties investigated.

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Relation of Time of Pruning to Performance of Grapes

By C. A. Magoon and I. W. Dix, *U. S. Horticultural Station, Beltsville, Md.*

PERENNIAL interest is manifested by growers of grapes in the matter of the best time to prune the vines and particularly in the effect on the vine of severe bleeding which follows late pruning in the spring. General recommendations have been to delay the pruning, if feasible, until after danger of heavy freezing is past, in order to avoid winter killing of the pruned canes, and to complete the pruning early enough in the season to prevent heavy bleeding of the vines, which, it has been thought, might have a detrimental effect. In order to secure more definite information a pruning experiment was initiated in the fall of 1934 at the United States Horticultural Station, Beltsville, Maryland, in a vineyard unit devoted to a study of the performance of Concord, Ontario, and Delaware varieties when grown under different vineyard practices. This report records the findings of this experiment.

Vines and Methods

One hundred and twenty vines of each of the three above-named varieties, growing on their own roots, entered into the experiment. These made up every second row of a 1½-acre vineyard plot, totaling 10 test rows with a guard row on either side. These vines were spaced at 8 feet in the row and the rows were 10 feet apart. Single guard vines at either end of the rows did not enter into the experiment. The arrangement within each row was as follows: six vines of Concord, followed by six of Ontario, and these in turn by six of Delaware, and then these groups followed by a second set of six vines of each variety arranged in the same order.

The vineyard unit occupies a hill slope having a northwestern exposure with a maximum difference in elevation of about 25 feet. The rows run in a north-south direction.

Prior to the fall of 1936 the vineyard received general cultivation with a yearly application of nitrate of soda at the rate of 300 pounds per acre, and a summer cover crop of cowpeas was grown between the rows. Beginning in the fall of 1936 cornstalk mulch was applied to alternate rows of the vines being considered here and this was renewed each fall thereafter. The other rows were given clean cultivation. In the spring of 1937 nitrate of soda at the rate of 1 pound per vine and a 5–8–5 complete fertilizer at the rate of ¾ pound per vine were applied in alternate bands running at right angles to the rows, in such a way that one-half of the vines in each varietal group received the nitrate and the other half the complete fertilizer. This treatment was repeated each spring subsequently.

The vines were trained according to the 4-cane Kniffin system and a uniform system of pruning was followed throughout, one bud being left on the pruned canes for each ounce of wood removed, the weight considered being an average of the previous and the current seasons'

removals. The pruning was done by the same workers throughout the duration of the experiment and every endeavor made to make the results of the work as trustworthy as possible.

The pruning was begun on the first of November of each year, or as close to that date as possible, and repeated at monthly intervals up to and including the first of April. On the first of November the first vine of each set of six of the three varieties was pruned, on December 1 the second vine, and so on until on April 1 the last vine of each set was pruned. The individual vines were thus pruned on the same dates for each year of the test period, and vines pruned at each date were distributed throughout the vineyard block.

At the time of the November pruning the leaves had but recently dropped from the vines, and heavy bleeding invariably followed the April pruning.

Experimental Findings

The performance of the vines of the three varieties in the production of fruit and of wood is shown in Table I, and since the total dry matter, from fruit and wood combined, would seem to be a more accurate index of the vitality of the vines, figures for this are also included.[1]

TABLE I—Showing Performance of Vines of Concord, Ontario, and Delaware Varieties when Pruned on Different Dates. (Individual Values Represent the 5-Year Average Production for Each Monthly Test Group—20 Vines Unless Otherwise Indicated)

Weight	Nov (Ozs)	Dec (Ozs)	Jan (Ozs)	Feb (Ozs)	Mar (Ozs)	Apr (Ozs)
			Concord			
Fruit						
Fresh	782	855	830	801	825	905
Dry	328	359	349	336	347	380
Wood						
Fresh	295	189	229	211	213	223
Dry	161	103	125	115	116	122
Total						
Dry	489	462	474	451	463	502
			Ontario			
Fruit						
Fresh	494*	534*	505	563	559	542*
Dry	207*	224*	212	236	235	228*
Wood						
Fresh	117*	112*	103	108	107	90*
Dry	64*	61*	56	59	58	49*
Total						
Dry	271*	285*	268	295	293	277*
			Delaware			
Fruit						
Fresh	516*	460**	464*	433*	461*	510*
Dry	217*	193**	195*	182*	194*	214*
Wood						
Fresh	183*	134**	162*	154*	153*	162*
Dry	100*	73**	88*	84*	84*	88*
Total						
Dry	317*	266**	283*	266*	278*	302*

*19 vines.
**18 vines.

[1]The dry weight in the case of fruit was taken as 42 per cent of the fresh, this value being derived from the published tables of Atwater and Bryant (1). In the case of wood, 54.6 per cent of the fresh weight was used, this figure having been determined by the writers in the course of the present investigations.

The individual values represent in ounces the 5-year averages for the 20 vines (in some instances 19 vines and in one case 18) in each group pruned on the different dates.

It is to be noted that in no case did evident injury to the vines occur as the result of either early or late pruning. With the Concord and the Delaware varieties the total production figures were actually a little higher for the November and the April pruned vines than those for the other months, but these differences were not significant. In the case of Ontario the November and April figures were actually a little below those for some of the other months, but here also the differences were not significant.

Since a number of factors affected the performance of the vines, the relative importance of which was not known, such as: different cultural and fertilizer treatments, variations in vineyard elevation, soil heterogeneity, and so on, in addition to the differences in time of pruning, it was thought desirable to make an analysis of the variance to see whether the conclusions as to the negative significance of the pruning dates based on a visual inspection of the summarized data were sound. The results of this analysis are presented in Table II.

It is to be noted that in the case of the Ontario variety three vines died during the course of the experiment, and seven in the case of Delaware; hence figures for these were not available. To make possible the analysis of variance for these two varieties, therefore, it was necessary to substitute production figures for the missing vines. The figure used in each case was the mean production of the individual vines of each variety, and the slight error introduced thereby was compensated for by a corresponding reduction in the degrees of freedom. The calculations were based on the dry weight figures for fruit and wood combined.

From Table II it is seen that while some of the factors mentioned played significant roles in determining variations in vine performance, the variance due to the different pruning dates in all three varieties was the least of all in magnitude, and neither in itself nor in its interaction with other factors showed significant values.

TABLE II—Source and Significance of Variance in Grape Pruning Experiment

Source of Variance	Concord			Ontario			Delaware		
	Degrees of Freedom	Mean Variance	"F" Value	Degrees of Freedom	Mean Variance	"F" Value	Degrees of Freedom	Mean Variance	"F" Value
Cultural treatments	3	14,261	1.312	3	17,500	2.683	3	35,610	3.507*
Pruning dates	5	7,085	.651	5	2,455	.376	5	5,818	.573
Replicates	4	390,822	35.957**	4	239,248	36.678**	4	127,842	12.590**
Interactions:									
Cultural treatments ×pruning dates	15	7,401	.681	15	8,406	1.289	15	17,536	1.727
Cultural treatments ×replicates	12	30,150	2.774	12	18,485	2.834*	12	49,699	4.895*
Pruning dates ×replicates	20	11,113	1.022	20	8,990	1.378	20	8,786	.865
Remainder	60	10,869		57	6,523		53	10,154	

*Significant to the 5 per cent point.
**Highly significant.

Discussion

Shedd (3), in his studies on the mineral composition of the sap of a wild grape vine, noted that weakening resulted from the periodic loss of sap from a branch over a period of 4 years, but one would hardly be justified in concluding from this that the loss of sap from a completely pruned vine would necessarily result in a weakening of the entire plant. Repeated temporary checking of growth in one branch, which heavy bleeding might cause, might very well result in the remaining unbled branches assuming leadership over the affected branch. In the same paper it was reported that the mineral content of the sap at the beginning of the sap flow was less than at the end. From this it would appear that the loss of sap from vines not yet showing spring growth is a less serious matter than might be the case where seasonal growth had been initiated. Loomis (2), in a study of the effect of late pruning, noted that a delay in foliation followed heavy bleeding, but that the vines promptly made up for the delay and at the end of the season showed no reduction either of fruit or wood production over vines pruned during the fully dormant season. In the present pruning experiment no delay in foliation or other visible unfavorable effects were found as a result of late pruning. It is to be noted that vines showing heavy bleeding, in the present experiment, had not passed beyond the initial swelling of the buds. Pruning after growth was well under way might have given entirely different results.

Field observations made in sections of the country where very low winter temperatures are encountered have indicated that winterkilling of pruned canes may result from early pruning if followed by a heavy freeze, and in those sections it would be advisable to wait until danger of heavy freezing is past before beginning the pruning work. At this Station winter temperatures rarely go below –10 degrees F and it is believed that in sections of the country having winters no more severe than this the pruning may be begun safely as soon as the leaves have fallen in the fall.

Conclusions

The results of the present experiment on the pruning of Concord, Ontario, and Delaware grape vines at monthly intervals from the first of November to the first of April seem to warrant the conclusion that at least at this and the more southern latitudes pruning may be done without injury to the vines at any time after the leaves have fallen in the fall up to the time the buds begin to swell in the spring, and that even in the more northern sections of the country heavy bleeding of the vines should cause no anxiety.

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Time Limits of the Grape Bud-Graft Method

By Elmer Snyder and F. N. Harmon, *U. S. Department of Agriculture, Fresno, Calif.*

EXPERIMENTS were started in 1939 to determine the time limits within which the grape bud-graft method (1) could be successfully practiced—a question frequently asked by grape propagators. The tests were conducted at the United States Horticultural Field Station, Fresno, California, where the climatic conditions as indicated in Table I are characterized by dry hot summers and mild winters with most of the rainfall occurring during the winter months. Surface irrigation was used during the summer months to augment the seasonal rainfall.

The stock vines used in these tests comprised a planting of 520 1-year-old Solonis x Othello, No. 1613 rootings which were planted in March 1939. The stock rootings were planted in rows 8 feet apart and 2 feet apart in the rows. The grape bud-grafts were made on these rootstocks in approximately equal portions on the first and fifteenth of each month, starting with July 1, 1939 and ending with July 1, 1940 inclusive. The Sultanina was used as the scion variety.

From July 1, 1939 to January 1, 1940 inclusive, the scion buds were obtained directly from the parent vines at the time of bud-grafting. From January 15, 1940 to July 1, 1940 inclusive, the buds were obtained from cuttings made from mature canes which were held dormant in a sand bed or, in the case of the later bud-grafts, were kept dormant by refrigeration. The buds used July 1, 1939 were in the white bark

TABLE I—Summary of Results From Bud-Grafting Grapes at Different Seasons of the Year

Date of Bud-Grafting	Mean Temperature For Month (Degree F)	Total Rainfall For Month (Inches)	Buds Growing (Per Cent)	Average Weight Growth Per Vine, October 1940 (Grams)	Average Mature Wood Per Vine, October 1940 (Per Cent)
1939					
July 1	82.0	.00	60	490.3	67
July 15	—	—	100	488.8	68
August 1	81.3	.00	79	462.5	67
August 15	—	—	95	380.1	72
September 1	73.0	.38	85	335.4	77
September 15	—	—	95	287.6	80
October 1	62.5	1.80	90	165.5	76
October 15	—	—	95	439.7	78
November 1	52.3	—	70	391.5	79
November 15	—	—	85	225.1	79
December 1	47.8	.20	84	215.8	81
December 15	—	—	90	256.1	85
1940					
January 1	45.8	6.47	75	199.5	83
January 15	—	—	75	480.7	75
February 1	51.5	4.24	95	501.4	75
February 15	—	—	90	569.8	72
March 1	57.7	.93	85	399.5	81
March 15	—	—	85	380.4	78
April 1	62.8	.24	90	214.6	83
April 15	—	—	95	152.0	83
May 1	71.3	.00	95	170.9	80
May 15	—	—	85	26.5	55
June 1	81.2	.03	95	38.8	60
June 15	—	—	100	33.3	39
July 1	82.3	.00	72	33.9	8

stage, having passed the real green stage but still showing no mature brown coloring. The bud chips used on July 15 were taken from canes, green at the nodes but showing a brown coloring of the bark. Bud chips used August 1 were from canes slightly green at the nodes, but with brown coloring predominating otherwise. The bud chips used on August 15 and on the later budding dates were brown and apparently mature.

In the case of vines budded from July 1, 1939 to March 15, 1940, the stock portion above the bud-graft was removed on March 20, 1940. In the case of all vines budded after March 15, the bud were inserted in the stocks on the given dates and 1 week later the stock portion above the bud-graft was removed. At the time the stock portion above the bud-graft was removed, the bud-graft union was covered with sand.

Table I gives a summary of the seasonal data obtained. The percentage of buds growing was high for nearly all periods. Although the table shows slightly lower percentages for some of the colder periods, buds inserted on December 15 gave a 90 per cent stand. In general, however, the period from November 1 to January 15 was not quite as satisfactory in percentage of stand as the preceding or following periods. In order to picture the average growth weights in linear terms, vines were weighed and measured. It was found that 1 gram of green growth was equivalent to approximately 2½ inches linear cane, while 1 gram of mature wood was equivalent to about ¾ inch. Thus a bud producing 200 grams, 80 per cent mature wood, would approximate 10 feet of mature wood and 8 feet of green growth. On this basis, the average growth per vine was adequate in all except the very late spring periods. The growth produced by buds inserted between November 15 and January 1 averaged lighter than buds inserted before or after these periods. This is believed to be due, however, to less favorable soil conditions where the rootings budded on these dates were growing. The growth weights produced during these periods, however, were satisfactory for commercial practice. The percentage of mature wood produced was sufficient in all lots except those budded late, or from May 15 to July 1. The growth from buds set at these later periods did not mature sufficiently to recommend these periods for commercial practice.

Within the limits of these tests, bud-grafting for experimental purposes may be practiced at any season of the year and a satisfactory stand of growing buds may be obtained. The shorter growing season available for buds inserted during the periods from May 15 to July 1 which resulted in weak and immature growth would eliminate these periods from commercial practice.

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An Instance of Boron Deficiency in the Grape Under Field Conditions

By L. E. Scott, *Sandhill Experiment Station, Columbia, S. C.*

IN JUNE 1939 an abnormal foliage development was noticed on certain vines of the experimental vineyard at the Sandhill Experiment Station near Columbia, South Carolina.[1] The nature of the symptoms suggested that the trouble might possibly be attributed to a deficiency of boron. Treatment of a few vines with borax in 1939 and a more extensive test with borax treatments in 1940, when the symptoms developed in a much more aggravated form, corrected the abnormal condition.

In an examination of the recent excellent bibliographies (1, 4) on boron as a plant nutrient only two citations were found concerning the deficiency of boron in the growth of grapes and these were confined to symptoms developed in water cultures (2, 3). Evidently boron deficiency has not developed or has not been diagnosed as such under vineyard conditions.

The Vineyard

The vineyard soil, typical of the Sandhill region of the Carolinas, is classed as a deep phase of Norfolk sand, very deficient in organic matter as well as in many of the plant food elements. Responses to applications of calcium, magnesium, and other so-called minor plant food elements have been obtained on certain crops grown in this soil. However, in the experimental vineyard fairly satisfactory vine growth and production have been secured. The vineyard has received annual applications of a "complete" fertilizer at the rate of 600 to 800 pounds per acre. In addition, 1,500 pounds per acre of dolomitic limestone was applied in 1932, and 1,000 pounds per acre of basic slag in 1938. The pH of the soil was about 5.8 in 1939. The vines ranged in age from 5 to 9 years.

1939 Results

The foliage symptoms noted in June 1939, consisted of a well developed pattern, with areas toward the leaf margin and between the leaf veins becoming chlorotic. These chlorotic areas remained intact even in severe cases with little or no breaking down of tissue or burning of the leaf margins. The surface of affected leaves was abnormally roughened with raised areas between the veins. This resulted in a cupping of the leaf toward the under side, which was very noticeable in certain varieties. Premature defoliation did not occur. In some of the more severely affected vines, especially in the variety Ontario, there was observed a very decided tendency toward unusual development of lateral buds on the current season's shoots.

On June 22, 1939, two or three vines of each of 10 varieties which showed these abnormal characters were treated with commercial borax

[1]The experimental vineyard at the Sandhill Experiment Station near Columbia, is in connection with a cooperative grape project between the South Carolina Experiment Station and the Bureau of Plant Industry.

at the rate of 10 pounds per acre. This was applied to the soil on either side of the vine. The varieties treated were Delaware, Lenoir, Herbert, Herbemont, Barnes, Extra, Portland, Ontario, Concord, and Catawba. Examination of the new growth produced on these treated vines in July and August showed no evidence of abnormality, although the older leaves which were affected before the treatment remained chlorotic. However, the late growth on untreated vines also showed little evidence of abnormal symptoms.

1940 Results

The spring of 1940 was unusually late. In the early part of May it was noticed that the shoots on a number of varieties were developing very abnormally, with pronounced dwarfing of growth, a tendency toward the development of several shoots from a single node, and the initiation of lateral bud growth on these short, stunted shoots. The internodes were very short and the leaves small. Flower clusters developed very conspicuously on these shoots, but were twisted, malformed, abortive, and failed to set fruit. Other vines showed less extreme symptoms, similar to those observed in the previous year. Upon examination of the vines treated with borax in 1939 it was found that none of those vines were affected but had developed normally in every respect.

The differences in the 1940 yields between the vines treated with boron in 1939 and untreated vines were very striking. These yields are given in Table I. In many instances untreated vines failed completely to set fruit while in others the bunches were ragged with many undeveloped berries. The vines treated in 1939 were, in each variety, those showing the most severe symptoms at the time of treatment.

TABLE I—Effect of Boron Treatment in 1939 on 1940 Yields of Grapes

Yield in Pounds Per Vine (Two to Five Vines Each)

Variety	Treated Vines	Untreated Vines
Catawba	15.0	1.4
Delaware	2.8	0
Extra	9.4	5.2
Lenoir	41.8	2.5
Concord	5.0	1.3

On May 22, 1940, half of the vines of each variety in the vineyard were treated with borax. On July 8, the new growth on these treated vines was developing normally while on many of the untreated vines the abnormal symptoms continued. Again, as in 1939, it was noted that the later growth, even on the untreated vines, was not as badly affected as the early season growth.

Varietal Differences

Great differences in varietal response to the deficiency existed. A list of the varieties arranged according to the severity of the symptoms noted is given in Table II. In general, the weaker varieties such as Delaware, Ontario and President were more severely affected than the

TABLE II—Relative Susceptibility of Certain Grape Varieties to Boron Deficiency as Indicated by Symptoms Developing in 1939–1940 in the Sandhill Experiment Station Vineyard

Severely Affected*	Moderately Affected†	Apparently Not Affected‡
Ontario	Captivator	Hanover
Ives	Barry	Golden Muscat
Geneva	Dutchess	Champion
Gaertner	Worden	Cloeta
Empire State	Diamond	Fredonia
Seneca	Elvira	R. W. Munson
Wyoming	Champagne	Isabella
Hartford	Lutie	Edna
Sheridan	Minnie	Portland
Triumph	Lucille	Amalaga
Carman	Extra	Bailey
Headlight	President	Also varieties grafted on vigorous rootstocks
Herbemont	Herbert	
Delaware	Concord	
	Catawba	
	Niagara	
	Caco	
	Lenoir	
	Last Rose	

*Early season dwarfing of growth and lateral bud development. No fruit produced.
†Chlorotic pattern in foliage but no stunting in early season. Fruit production more or less affected.
‡No foliage symptoms, possibly fruit production affected.

rank varieties, such as R. W. Munson, Bailey, and Champion which showed little or no evidence of the deficiency. However, the very vigorous varieties Barnes and Lenoir both showed very clear foliage symptoms although no early season dwarfing. It should also be noted that Lenoir exhibited a striking yield difference between treated and untreated vines even though the affected vines were quite vigorous. It is probable that the lack of vigor and the progressive decrease in productivity of certain varieties during the past few years have been due in part to this boron deficiency.

It was also observed that otherwise susceptible varieties when grafted on vigorous rootstocks did not show any symptoms of boron deficiency. Especially noticeable was the performance of Ontario and Lomanto in this respect. On their own roots those varieties were extremely affected but when grafted on Dog Ridge, Rupestris St. George and other stocks the vines developed perfectly normally.

TABLE III—Boron Content of Mature Leaves of Treated and Untreated Grape Vines, August 1940 (by Spectro-chemical Determination)

Variety	Treatment	Condition of Vine at Time of Sampling	Boron (PPM)
Catawba	Boron—June, 1939	No symptoms; heavy crop	18
Catawba	No boron	Distinct foliage symptoms; no crop	6
Delaware	Boron—June, 1939	Fair crop; no symptoms of deficiency	23
Delaware	No boron	No crop; severe foliage symptoms	6
Lenoir	Boron—June, 1939	Heavy crop; vigorous vine growth	19
Lenoir	No boron	No crop, vine growth vigorous; shows leaf symptoms	6
Ontario	Boron—May, 1940	No crop, symptoms severe in early season; "dwarfed"; no symptoms on new growth at time of sampling	54
Ontario	No boron	No crop, extreme symptoms in early season, then grew out of it; new growth showed symptoms at time of sampling	24

Spectro-chemical Analysis

The boron content of leaf samples from treated and untreated vines of several varieties was determined by spectro-chemical analysis[2] (Table III). These analyses are strikingly in accord with the observed deficiency symptoms. It is interesting that Ontario, which seems to be very susceptible to the deficiency, showed a much higher boron level in both treated and untreated vines than the other varieties.

Summary

Application of boron in the form of borax corrected an abnormal foliage development and unfruitfulness in a vineyard on Norfolk sand. The foliage symptoms varied with variety and the severity of the deficiency. In less severe forms, the deficiency caused the development of chlorotic areas near the margin and between the leaf veins. In younger leaves this chlorosis was diffused, giving the entire leaf a lighter or more yellow color than normal. In mature leaves the chlorotic areas were clearly defined. The surface on the leaf was roughened and there was commonly a cupping toward the under surface.

In severe forms of the deficiency shoot growth in early spring was extremely dwarfed, with a pronounced tendency toward multiple development of shoots from a single node causing a "witch's broom" appearance. Lateral buds on the stunted shoots were forced into growth. Internodes were very short and leaves were only a fraction of their normal size. Flower clusters that developed appeared very prominent but were twisted, malformed, and abortive, failing to set fruit. From observation of the performance of certain varieties such as Lenoir it is likely that boron deficiency may cause unfruitfulness, even when there is little evidence of effect on vine vigor or of foliage symptoms of deficiency. Severely affected vines make little growth throughout the season. However, vines less severely affected may outgrow the early season symptoms and appear normal later in the year.

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[2]The writer is indebted to B. C. Brunstetter and A. T. Myers for the spectro-chemical analyses.

Maturity Studies with California Grapes I. The Balling-Acid Ratio of Wine Grapes

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IN a previous report of the Division of Viticulture (10) the importance and use of the Balling-acid[1] ratio as a measure of the maturity and eating quality of California table grapes has been demonstrated. Mathieu (5) has also demonstrated the utility of such a ratio in table grape maturity studies in France. Similar data are here presented on the importance and utility of this ratio in studies with wine grape varieties of *Vitis vinifera*. These studies, which are one phase of a project concerning the utility of the various varieties of grapes, have been mainly directed towards the elucidation of the maturity factors influencing the quality of table wines (8). Results are also presented concerning the requirements of wine grapes for dessert wines. The use of the B/a ratio as one means of evaluating grape varieties is also discussed.

It has long been recognized that the optimum maturity of grapes for table wines is from 20 degrees to 24 degrees Balling,[2] depending on the variety, season, and district, while the best dessert wines are produced from grapes having a Balling which is over 24 degrees (1). It is also known that even with a favorable Balling, varieties of recognized merit in certain seasons or when grown in certain districts fail to yield satisfactory wines.

Ferré (3) has indicated the relation of the B/a ratio to the quality of the wines in the Côte d'or region of France. The minimum acidity for the best wines was 0.66 and the maximum B/a ratio at this acidity was 40. The minimum needed to produce a balanced wine was about 27 at 24.5. Balling. Under most European conditions, however, the climate is such a limiting factor that the balance of sugar and acid has been considered primarily only in the cool seasons when amelioration is necessary, see, for example, Kramer (4). In Algeria, where the climatic conditions are much warmer, the importance of the sugar-acid balance is recognized. Dugast (2) states that if the total acidity is below 0.6 per cent addition of acid is recommended, and that from 0.6 to 0.7 per cent addition of acid is desirable if the sugar content is high. He recommends raising the acid to 0.8 per cent. Similar recommendations for increasing the acidity have been given by Pato (6) in Portugal. The apparent B/a ratio recommended for grapes to be used for table wines in these two districts is below 30.

Experimental Procedure

The studies reported were mainly conducted at Davis and the utility of the results, as will appear later, are mainly applicable to districts

[1]Hereafter in this paper the Balling-acid ratio will be reported simply as the B/a ratio.

[2]Occasionally under particular circumstances a fine variety, the wine of which is destined for long aging, may require a slightly higher percentage.

having climatic conditions similar to those of this region. At least 10 vines are represented for each variety. Sampling was done at random using about 10 pounds of fruit per collection. A continuous type press was utilized to extract the juice. Early in the season neither filtration nor centrifuging of the juice was necessary in order to secure a clear sample for analysis. All analyses, with few exceptions, were conducted the same day the samples were collected. Balling hydrometers calibrated in 1/10 degree, and which had an enclosed thermometer for correcting for temperature differences, were used. A sample of this juice was titrated with 0.0333N sodium hydroxide and the results calculated as grams of tartaric acid per 100 milliliter of juice. The rôle of the pH and of the different acids of the musts will be discussed in a later paper.

Factors Influencing the Balling-Acid Ratio

Seasonal Conditions:—The B/a ratio has been shown to be greatly affected by seasonal conditions, Winkler and Williams (11). In our studies the average B/a ratio of 30.6 for 90 varieties at 22 degrees Balling in 1939 is but slightly different from that of 32 for the same varieties at the same degree Balling in 1940. This is due to the small difference in climatic conditions during the ripening period in the two seasons. During maturation in 1939 the summation of heat as day degrees above 50 degrees F was 599 while during 1940 it was 585. Much more marked differences in the B/a ratio have been noted by Winkler and Amerine (8) between the 1935 and 1936 seasons when there was a much greater difference in temperature conditions. In 1935 at 22.1 degrees Balling there was a B/a ratio of 36.2, while in 1936 at 23.0 degrees Balling the ratio increased to 46.0. These data were for 240 comparisons. The 1936 season was approximately 10 per cent hotter than 1935 for the season as a whole but for the ripening period alone it was over 20 per cent warmer. The small differences between 1939 and 1940 made the results of these seasons very useful for comparing the B/a ratio of a large number of varieties as reported later.

Regional Conditions:—Regional influences are important in California. Winkler (10) has previously shown that the differences in climatic conditions between the important grape-growing districts of California markedly influence the B/a ratio. With table grapes this influence has been sufficiently great to bring about the establishment of different marketing standards for certain districts.

The B/a ratio of several varieties of wine grapes at 22 Balling when grown in a hot and in a warm section of California are reported in Table I. The summation of heat during the maturation period at Davis was approximately 30 per cent less than that at Sanger. In Table I there are 36 possible comparisons between Davis and Sanger. In 33 there is a lower B/a ratio at Davis, in one there is no difference, and in two cases at 20 degrees Balling, when the sampling and analytical errors are greater, a slightly higher ratio was found at Davis than at Sanger. These differences are the result of significant changes in the total acidity. Averaging the comparative samples, the figures at 20 degrees Balling are 34.2 for Sanger and 27.4 for Davis. At 22 degrees

TABLE I—BALLING-ACID RATIO OF WINE GRAPES FROM SANGER AND DAVIS AT 20, 22, AND 24 DEGREES BALLING (1940)

Variety	20 Degrees		22 Degrees		24 Degrees	
	Sanger	Davis	Sanger	Davis	Sanger	Davis
Bastardo	—	21	31	28	40	33
Beclan	32	30	51	36	—	41
Cabernet Sauvignon	23	21	33	28	46	39
Carignane	24	26	40	32	—	—
Clairette blanche	51	24	—	31	—	38
Colombard	29	25	37	32	51	41
Folle blanche	43	25	—	30	—	—
Mission	31	26	39	35	48	47
Mondeuse	33	30	40	40	—	48
Mourisco preto	34	27	44	34	—	41
Muscat of Alexandria	40	29	58	36	—	44
Palomino	36	38	61	51	—	65
Petite Sirah	34	27	51	36	—	—
Pinot blanc	—	26	36	35	46	44
Refosco	36	28	45?	38	—	49
Semillon	33	28	42	37	52	45
Trousseau	—	19	32	27	42	38
Average B/a*	34.2	27.4	42.0	35.0	47.0	42.1
Average acidity†	0.585	0.730	0.524	0.629	0.510	0.570

*Averaged only where both districts represented in same year.
†Calculated acidity necessary to produce the B/a ratio given.

Balling they are 42.0 to 35.0 and at 24 degrees 47.0 to 42.1. The acidities necessary to secure these average ratios are 0.59 to 0.73 at 20 degrees Balling, 0.52 to 0.63 at 22 degrees, and 0.51 to 0.57 at 24 degrees, respectively. The average difference at 20, 22, and at 24 degrees Balling indicates that there is 18.1 per cent more acidity in the grapes grown at Davis than in those produced at Sanger.

Effect of Crop:—It is somewhat difficult to secure accurate quantitative data concerning the influence of crop on the ratio of sugar and acid. That there is an effect, however, seems quite clear. In any consideration of the effect of the amount of crop, it must be remembered that the B/a ratio is influenced by two factors, namely, the sugar and acid contents of the fruit. It may be increased by either an increase in the sugar content or by a reduction in the acidity of the fruit.

Thinning tests in 1937 and 1938 in which the clusters per shoot were reduced shortly after blooming to two and one, respectively, have not shown a clear-cut influence on the B/a ratio. Neither did Winkler (9) show a definite relation of crop to the B/a ratio in earlier work where he varied the number of leaves to a cluster from 2 to 30 in Muscat and 4 to 24 in Malaga grapes. Viala and Rabault (7) also failed to secure a uniform change in the B/a ratio when the leaf area per fruit was reduced.

The pruning practices of the cooler locations of Europe are apparently based on drastically reducing the crop in order to secure sufficiently early ripening as well as to obtain a favorable B/a ratio. Under most California climatic conditions such extreme reduction of crop would be harmful. The frosts of the spring of 1936, for example, did reduce the crop and the resulting vintage was much less satisfactory for many varieties due to the very high B/a ratios which prevailed. (See also Winkler and Amerine (8) for the important influence of climatic conditions during ripening on this crop.) It should be noted,

TABLE II—THE EFFECT OF CROP ON THE BALLING-ACID RATIO AT 20, 22, AND 24 DEGREES BALLING

Variety	1939				1940			
	Crop (Tons Per Acre)	The B/a at Ballings of			Crop (Tons Per Acre)	The B/a at Ballings of		
		20 Degrees	22 Degrees	24 Degrees		20 Degrees	22 Degrees	24 Degrees
Dolcetto	4.8	29	41	53	3.8	28	34	39
Mathiasz y-ne	2.3	29	43	57	7.0	44	55	65
Muscat Canelli	3.1	24	35	46	1.8	23	31	40
Neiretto	1.8	18	24	33	3.3	24	32	41
Pagadebito	3.5	25	39	53	5.4	34	51	63
Sylvaner	4.1	22	30	36	3.15	19	24	29

however, that where there is a light crop the grapes *may* be picked somewhat earlier and the total acidity need not diminish to such an extent if the picking date is carefully watched.

Overcropping is quite common in California and its influence is of considerable practical importance. It is common experience that when grapes overcrop they may fail to adequately ripen. The rate of change of the Balling is then markedly reduced. In a few cases the acidity also does not change at its usual rate but in most cases there is a marked reduction in acidity and the B/a ratio increases while the Balling stays practically constant. The decrease in acidity may be due simply to the very long time during which the grapes must be left on the vines to ripen.

A similar situation to the above may occur with only a moderate crop in years following excessive over-cropping that has greatly depleted the reserves of the vines. This condition, along with the rehabilitation of the vines in a number of vineyards is being investigated.

Data are given in Table II on the influence of crop on the B/a ratio. Examples of varieties showing a high crop in 1939 or in 1940 are given. The vines are 4 and 5 years old, and for the capacity of the vines the larger crop figures given represent an overcrop. In the year of the overcrop the B/a ratio is greater at 20, 22, and 24 degrees Balling than in the other year when the crop was approximately normal. If the rate of ripening is a function of leaf surface, as indicated by Winkler (9), this would be expected since the grapes must remain on the vines a much longer period of time in order to attain the same percentage of sugar and the acid content of the fruit will gradually diminish.

Influence of Variety:—The largest and most consistent differences in the B/a ratio are the result of varietal influences. The difference between varieties is illustrated by the grouping of a number of representative varieties according to their B/a ratio under A, B, and C in Table III. These data are based on at least four collections made during the ripening period, September to October, for a large number of varieties. These Balling readings were plotted against the acidity. The acidity at Ballings of 20, 22, and 24 degrees was then taken from the curve and the B/a ratio at these Ballings calculated.

The influence of soil conditions, humidity, and exposure has not been studied thus far.

TABLE III—THE BALLING-ACID RATIO OF TYPICAL WINE GRAPE VARIETIES GROWN AT DAVIS IN 1939 AND 1940 AT BALLINGS OF 20, 22, AND 24 DEGREES

Varieties	1939	1940	1939	1940	1939	1940
A. Varieties With Ratios of Below 28.6, 31.4, and 34.3 at Ballings of						
	20 Degrees		22 Degrees		24 Degrees	
Affenthaler	17	18	24	25	34	31
Gamay Beaujolais	20	22	27	28	33	34
Grignolino	12	15	17	22	25	29
Negrara di Gattinara	15	22	25	28	33	34
Sangioveto	14	12	18	17	25	22
B. Varieties With Ratios Exceeding 28.6, 31.4, and 34.3 at Ballings of						
	20 Degrees		22 Degrees		24 Degrees	
Beclan	29	30	39	36	48	41
Griolla di Vino	31	29	43	39	57	50
Malmsey	31	34	40	45	51	51
Mathiasz y-ne	29	44	43	55	57	65
Muscat di Terracina	37	40	44	49	53	—
C. Varieties With Ratios Intermediate to Those of A and B						
	20 Degrees		22 Degrees		24 Degrees	
Bambino bianca	23	22	34	29	44	48
Boal di Madeira	23	27	30	33	46	39
Clairette blanche	21	24	28	31	38	38
Colombard	24	25	33	32	39	41
Muscat Canelli	24	23	35	31	51	40

UTILITY OF THE BALLING-ACID RATIO

The data of Table III not only indicate the differences in the B/a ratio of various varieties but they also show that these differences are of about the same magnitude at a given location in seasons that differ little climatically, as in 1939 and 1940. The duplicability of the B/a ratio of the varietal differences during four quite similar seasons is shown for several representative varieties in Table IV.

This limited fluctuation of the B/a ratio within a given region when the seasonal conditions vary but slightly and when production is controlled, suggests its utility as a means of differentiating the various varieties from one another. If 0.70 per cent total acid be taken as the minimum value for musts intended for the production of dry table wines and if 0.70 per cent is also a maximum acid content for musts

TABLE IV—THE BALLING-ACID RATIOS OF REPRESENTATIVE VARIETIES AT DAVIS AT 20, 22, AND 24 DEGREES BALLING BASED ON WEEKLY COLLECTIONS THROUGHOUT THE SEASONS OF 1937 AND 1940

Varieties	1937			1938			1939			1940		
	20	22	24	20	22	24	20	22	24	20	22	24
Carignane	19	27	32	22	29	35	26	32	—	21	27	32
Chasselas doré	38	47	57	43	56	69	45	61	—	50*	56*	—
Muscat of Alexandria	33	38	52	33	42	51	27*	35*	48*	32	37	44
Petite Sirah	27	32	37	27	33	39	27*	36*	—	23*	32*	40*
Thompson Seedless	25	32	43	26	35	47	29	36	45	26	31	38

*Irregular collection dates, but at least four samples taken during the ripening period.

intended for sweet dessert wines, then certain minima and maxima in the B/a ratio may be established. Grapes are ordinarily harvested for the production of dry table wines at Ballings of 20 to 24 degrees, and usually at 22 to 24 degrees. Grapes intended for dessert wines should have Ballings exceeding 24 degrees. The B/a ratio at 20, 22, and 24 degrees Balling for 0.70 per cent total acid is 28.6, 31.4, and 34.3. Varieties which exceed these ratios at these Ballings, particularly at 22 and 24 degrees are less suited to the production of table wines than varieties having a lower ratio.

Dessert wines, on the other hand, require grapes with a minimum ratio of 34.3 at 24.0 degrees Balling. It is possible that certain varieties, Mourisco branco for example, have a ratio that is too high — over 60 at 24 degrees Balling — for sweet wines, but such cases are rare.

In Table III we have given some examples of varieties which fall into each of these classes, together with a few borderline cases. For purposes of classification we may divide the grape varieties thusly:

A. Varieties having a B/a ratio of below 28.6, 31.4, and 34.3 at 20, 22, and 24 degrees Balling. These are the typical dry, table wine grapes.

B. Varieties having a B/a ratio af over 28.6, 31.4, and 34.3 at 20, 22, and 24 degrees Balling. These are typical sweet dessert wine grapes.

C. Varieties which have a B/a ratio of below 28.6 and 31.4 at 20 and 22 degrees Balling but which exceed 34.3 at 24 degrees Balling. These varieties should be grown in a cooler district than Davis if dry table wines are to be produced from them.

A complete listing of varieties which have been tested by the above procedure and which fall into group A is as follows: Affenthaler, Alicante Ganzin, Aramon (at 20 and 22 degrees Balling), Barbera, Bolgnino, Bonardo, Carignane, Fogaruna, Gamay Beaujolais, Grignolino, Gros Manzenc, Grosse blau, Limburger, Malbec, Nebbiolo fino, Nebbiolo Tronero, Negrara di Gattinara, Negro amaro, Peverella, Picpoule noir (at 20 and 22 degrees Balling), Robasi di Piave, St. Macaire, Sangioveto, Tannat, Tinta amarella, Verdelho. Only two of these are white varieties, which indicates the scarcity of high acid white wine grape varieties for the production of dry table wines in the interior valleys of California. Under conditions as cool or cooler than those of Davis these varieties are well adapted to the production of dry table wines. Some of these varieties do not attain sufficient sugar or have too high a total acid for their use in the regular production of dry wines when they are grown in the coolest sections of California and, likewise, they may, when grown in the hottest districts, have too much sugar and insufficient acidity for the production of dry wines.

The varieties which have been tested at Davis and which fall in Group B include: Alicante Bouschet, Beclan, Charbono, Chasselas doré, Chenin noir, Coristano, Dolcetto, Flame Tokay, Grec rouge, Griolla di Vino, Gros Verdot, Kadarkas, Macaroli, Malmsey, Mantua di Pilo, Mathiasz y-ne, Marsanne blanc, Mondeuse, Muscat di Terracina, Muscat of Alexandria, Muscat Pantellana, Muscat St. Laurent,

Nasa Veltliner, Nicolas Horthy, Pagadebito, Palaverga, Palomino, Petite Bouschet, Refosco (?), Steinschiller, Terret Bourret, Vernaccia bianca.

The varieties in group C may be divided into two divisions. Those which only exceed the minimum ratios for dry wines at 24 Balling and which are in general considered table wine grapes. Varieties tested and found to fall into this group are: Antibo, Burger, Cabernet Sauvignon, Chenin blanc, Clairette blanche, Croetto Moreto, Erbalus di Caluso, Folle blanche, Gewürz Traminer, Kleinberger Riesling, Lagrain, Malvasia bianca, Orleans Riesling, Pinot blanc, St. Emilion, Sauvignon blanc, Semillon, Sylvaner, Wälschriesling, and White Riesling.

In the second division of group C are those varieties which exceed the maximum at both 24 and 22 and are, in general, considered to be dessert wine grapes. The varieties tested which fall in this group are: Bambino bianco, Boal di Madeira, Colombard, Corbeau, Ezerjo (F. P. I. No. 105001), Koptcha, Meunier, Mission, Montannacio, Muscat Canelli, Muscat Hamburg, Neiretto, Orange Muscat, Petite Sirah, Thompson Seedless, Trousseau (and Bastardo), Tinta di Madeira, Valdepeñas, and Vermentina Favorita.

The adaptations listed do not mean that the variety will make a quality wine of the type listed. But as far as the sugar and acid are concerned, there will be no difficulty in the production of the type of wine specified. Amount of crop, resistance to disease and insect pests, scion-stock interrelationships, time of blooming, ease of training and picking, color, aroma, flavor, ease of crushing, and stemming the grapes, and of fermenting and aging the wine are also factors in-

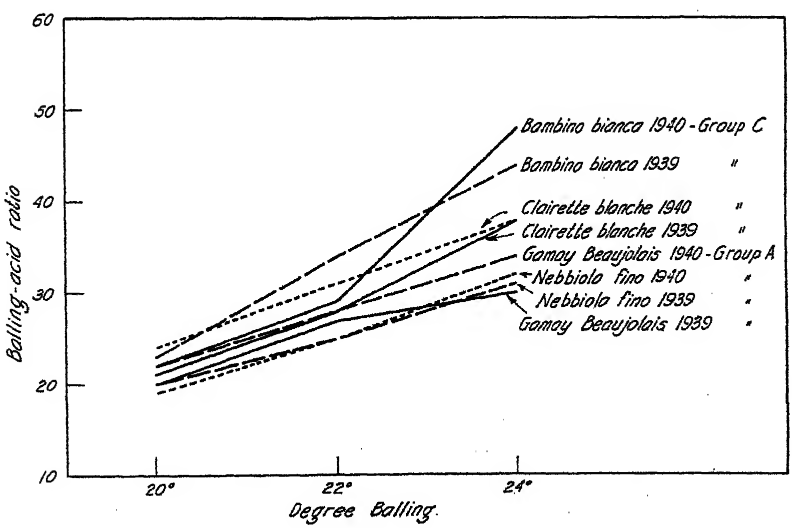

FIG. 1. Showing the rate of change in the Balling-acid ratio for two representative varieties in groups A and C.

fluencing the choice of a variety. The B/a ratio at several Ballings is, however, very helpful for a preliminary grouping of wine grape varieties.

The rate of change of the sugar and acid from 20 to 24 degrees Balling is greater for the varieties in group C than in those of A and B. This is indicated in Fig. 1. This rate of change is not a function of crop, since the varieties in group C are neither larger nor smaller producers than those in groups A and B. It is concluded that this is a fundamental difference of these varieties and further studies of the total acid balance and buffer capacity of these varieties during ripening will be carried out in order to elucidate this point.

Conclusion

The B/a ratio of grapes is influenced by the seasonal and regional conditions, the amount of crop, and the variety. The influence of the first two conditions is relatively direct, that of the amount of crop is not so clear cut, while that of variety is the most marked. The later influence dominates the others under the conditions of commercial grape production.

By utilizing the varietal differences in the B/a ratio at given degrees of Balling, a segregation of wine grape varieties into groups based on their best adaptation for given types of wine under a given environmental condition may be made. This segregation has been made for about 100 varieties grown at Davis. Three groupings have been made: Group A for varieties having ratios of below 28.6, 31.4 and 34.3 at 20, 22 and 24 degrees Balling; Group B for varieties exceeding these ratios at the three Ballings; and Group C for varieties which at 20 or 22 degrees have a ratio of below those given but which exceed the ratio at a higher Balling. Group A varieties are typical dry table wine grapes for Davis conditions. Group B varieties are typical sweet dessert wine grapes under these conditions and Group C varieties either should be grown under warmer or cooler conditions for production of dessert or table wines respectively. The adaptability of wine grape varieties for given types of wines can be predicted by this method, but the quality of the wines cannot be foretold.

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On Aerial Propagation of Grapes

By C. A. Magoon and I. W. Dix, *U. S. Horticultural Station, Beltsville, Md.*

THE propagation of grape vines from cuttings and by layering are time-honored procedures. They have, however, the disadvantage that an entire season is required to secure rooted plants and, in the case of layering, it is not always feasible to find suitable canes for the purpose. The aerial rooting of certain plant species, particularly of citrus, by the use of special rooting boxes placed about the stem or branch of the plant and filled with moist soil, sphagnum or other rooting medium, has been done by various investigators, and May and Bullen[1] some 13 years ago patented and dedicated to the use of the public a so-called "marcottage box" for the purpose. This consists of a slotted paraffined cardboard container the two halves of which, after packing partially full with a moist rooting medium, and placing about the portion of the plant to be rooted, telescope one within the other and when bound form a close fitting box within the contents of which the roots form.

Desiring to secure for physiological experiments during the current season a considerable number of rooted plants of different varieties which otherwise would not be available, aerial propagation was resorted to on vines in the varietal collection of the United States Horticultural Station, Beltsville, Maryland. The results were so favorable and the method so well adapted to practical use for various studies it was thought worth while to describe it for the benefit of those who may care to make use of it.

Experimental

The rooting receptacle used was a modification of the marcottage box of May and Bullen, specially adapted for use on grape vines, and was constructed from ordinary 3-inch paper mailing tubes with end discs of double-walled corrugated cardboard. To prepare, the mailing tube was cut into 4½-inch lengths with an ordinary hack saw, a ½-inch hole cut in the wall midway between the ends, and longitudinal slits made from this hole to each end of the tube. The end discs were marked off on sheets of cardboard — in this case material from second-hand corrugated cardboard packing cases — and the discs cut out with the small blade of a jackknife. A central ½-inch hole was cut in each and a slit made from this to the outer rim of the disc. Both tube and ends were then immersed for a few moments in hot melted paraffin and when cool were ready for use. Fig. 1 shows the parts and assembly of these to form the completed box, together with a quantity of moist sphagnum mixed with a small proportion of potting soil, which was used as the rooting medium.

The box was installed by opening the tube and slipping it around the cane at the node, allowing the side shoot to protrude through the

[1]United States Government Patent No. 1,655,731 issued January 10, 1928 to Eugene May, Jr. and Robert J. Bullen, Bureau of Plant Industry, United States Department of Agriculture.

FIG. 1. Showing parts and assembly of the rooting box, together with a small quantity of the rooting medium.

side hole. The tube was then closed and tied with cord at each end. One of the end discs was next slipped over the cane and fitted into the end of the tube, a retaining wire inserted to hold it in place, and the box packed with the moist sphagnum-soil mixture, pressing it closely about the cane. When full the other end disc was slipped onto the cane, pressed into the end of the tube and secured by wire as before. By using a wire about an inch longer than the diameter of the tube the box was easily attached to the trellis wire for support. No chemical root production stimulant was used. Fig. 2 shows the details of the installation.

In order not to interfere with renewal canes, boxes were not installed at nodes close to the main stem of the vine where the renewal canes ordinarily used develop. Fig. 3 shows a vine with nine installations in place.

The first set of rooting boxes was installed on May 27, 1940 at which time the side shoots were 12 to 18 inches long and the flower clusters fully developed. A second lot was installed on June 4 and 5. Nine different varieties were used, including: Bailey, Beacon, Concord, Dakota, Delaware, Ellen Scott, Herbemont, Niagara and Peabody. In these, 144 installations were made.

FIG. 2. The rooting box in place.

FIG. 3. Showing vine with nine rooting boxes in place.

On June 18, 22 days after the experiment was begun, examination showed well developed roots in all the rooting boxes first installed, that is, on the Beacon, Dakota, Niagara, and Peabody, and at this time the cane was severed at each end of the box, the protruding side shoot cut back to 3 to 4 nodes, and the new plants thus secured taken to the lath house for potting. Here the boxes were removed, the excess sphagnum and cane wood discarded, and the plants placed in water for a short time to soak the remaining sphagnum thoroughly. They were then put into 6-inch pots, using rich potting soil and watering well.

On July 2, 27 days after installation of the rooting boxes on the varieties Delaware and Herbemont, and 28 days on the varieties Bailey, Concord, and Ellen Scott, all new plants were removed from the vines and taken to the lath house for planting as before. In this case, more care was exercised to prevent wilting, the procedure being to sever the distal end of the cane first, then the excess growth of the side shoot, and finally the cane at the end of the box nearer the trunk of the vine. The new plants were put at once into buckets of water to keep them fresh until potted. After putting in the pots, about one-half of each leaf was removed. With this procedure the plants suffered less than those previously potted.

Positive rooting was obtained in every case with all varieties. Fig. 4 shows plants of Concord and Delaware as they were when taken from the rooting boxes.

In order to determine whether rooting would take place on canes of the present season's growth, on July 11 five rooting boxes were installed on new canes of the Beacon variety, with a mature wood control,

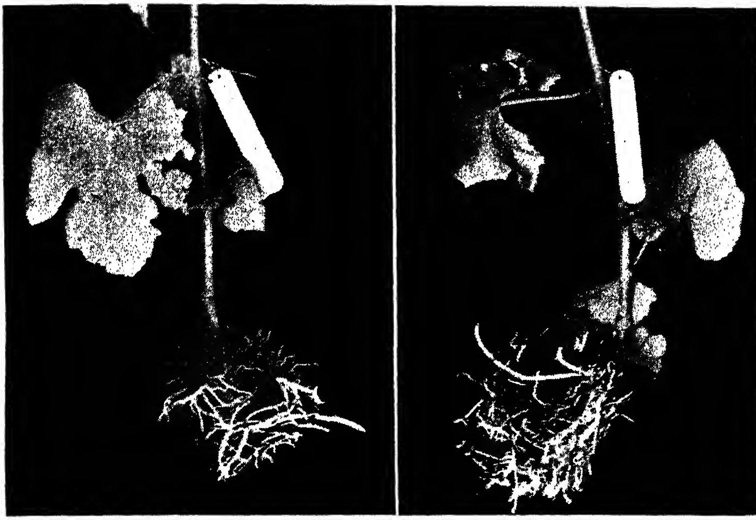

FIG. 4. Showing rooted plants of Delaware (left) and Concord (right) varieties as they were taken from the rooting boxes.

and two were put onto branches of muscadine vines to test the adaptability of the method to propagation of this type of grape. On August 12, 31 days after the boxes were placed on the canes, all showed abundant root growth both on green wood and mature wood of the Beacon variety. At this time no roots were found in the boxes on the muscadine vines but were found in abundance on August 23.

While positive rooting took place in every case, some plants at the time of or following the potting process were lost. This was due in part to injury in handling and in part, it is believed, to too early removal of the new plants from the mother vine. The heavy loss of plants of the Beacon variety was almost certainly due to the latter cause. The percentages of strong plants secured from the different varieties were as follows: Bailey, 100; Beacon, 33; Concord, 89; Delaware, 100; Ellen Scott, 78; Dakota, 100; Niagara, 94; Peabody, 94; and Herbemont, 78.

On July 30 growth of the potted plants in the lath house had been so rapid that it was necessary to transfer them to larger pots, and on August 8 all plants were removed from the lath house and put out in the open sunlight. Fig. 5 shows average plants of the different varieties as they appeared on September 28.

Discussion

One interesting observation made on the new plants derived from these experiments was that in the case of the Concord and Delaware varieties the new shoots developing from the axillary buds put out flower clusters, and in the case of one such cluster saved on a Delaware vine, nearly mature fruit was produced. None of the other varieties showed flower cluster development. This is of interest as indicating

FIG. 5. Photograph of average vines of the nine varieties of grapes taken on September 28, 1940. The amount of growth is indicated by the stakes which average 33 inches in height above the soil in the pots.

something of the time when flower cluster primordia are laid down in the buds of some grape varieties.

While it was found that rooted plants could be obtained from canes of the present season's development the plants derived were unable to make sufficient growth during the remainder of the season to make this method of propagation appear practical in this latitude. It might serve very well, however, in the more southern sections of the country having longer growing seasons. In our latitude the sooner the process is initiated after the new spring shoots have attained sufficient size to make the work feasible, the better the plants will be at the end of the season.

The prompt development of roots by this method should be of particular interest to cytologists concerned in studying chromosome behavior in grapes as abundant root-tip material of excellent quality may be obtained quickly and the result of colchicine and other special treatments can be promptly checked. No injury to vines is necessary for after examination of the tips all root growth may be rubbed off and the vine allowed to grow as usual.

The method is also particularly well adapted to the rapid and surer propagation of particularly valuable seedlings, chimeral material, and varieties not rooting readily from cuttings. For the practical propagation of standard varieties in commercial quantities, however, it would scarcely be feasible because of labor cost, except, perhaps, in special cases. The development of potted plants by this method for use in city yards and other special situations may merit some consideration.

The particular value of the method in the present case has been the saving of a year's time in the setting up of desired physiological experiments.

Carbohydrate Changes in Muscadine Grape Shoots During the Growing Season[1]

By T. A. Pickett and F. F. Cowart,[2] *Georgia Agricultural Experiment Station, Experiment, Ga.*

THE muscadine grape (*Vitis rotundifolia* Michx.) is propagated commercially by layering, since its cuttings are very difficult to root. While layering is an efficient means of propagation of this plant, the advantages of propagation by cuttings, when possible, are obvious especially where limited plant material is available. Work has been in progress at this Station for several years in an attempt to find a method of treatment whereby muscadine cuttings could be induced to root satisfactorily. Along with these studies, analyses for carbohydrate fractions were made on muscadine grape cutting wood collected at monthly intervals during the growing season, in an effort to relate the carbohydrate content with possible variations in rooting response obtained on such cuttings. This paper is primarily concerned with the results of these analyses.

Materials and Methods

Five similar samples of shoot pieces, 8 to 12 inches in length, were collected from 8-year-old Hunt muscadine vines on May 25, 1936, and at monthly intervals through November 25, 1936. These pieces were taken 12 or more inches back of the growing point and represented essentially mature wood, except in the very earliest samples. After the cuttings were removed from the vines, a lot of 100 was placed in sand in the greenhouse to note the rooting response. The others were cut into small pieces, thoroughly mixed, portions were used for moisture determinations, and 100-gram samples were preserved in 80 per cent alcohol. At a later date these 100-gram samples were extracted repeatedly with hot alcohol until all soluble carbohydrates were removed. The extracts were dealcoholized, cleared, deleaded, and the carbohydrates were determined by the Shaffer-Somogyi method (1). Sucrose was determined by inverting with invertase. Starch, by diastase plus acid, and acid hydrolyzable material by acid, were determined on the extracted resi-

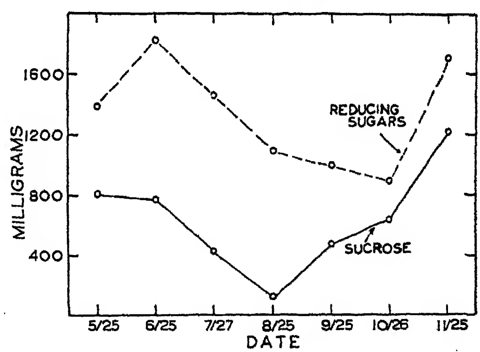

Fig. 1. Seasonal variation of reducing sugars and sucrose in muscadine grape shoots, expressed as milligrams of glucose per 100 grams dry weight.

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dues. The results of a few analyses on the extracts indicated that nonfermentable substances which might react with the Shaffer-Somogyi reagent were insignificant.

Results

The results of the analyses for reducing sugars and sucrose from the five similar samples for each month were averaged and are given in Fig. 1 in terms of glucose on a dry weight basis. On a fresh weight basis the data would be somewhat different since moistures decreased as the season progressed from 64.1 per cent in May to 44.8 in November, although the curves would assume about the same general shape.

There was a slight decrease in the sucrose content during the first part of the growing season, followed by a very large decrease until the minimum was reached at the August 25th sampling. The fruit of the muscadine grape matures at about this date in this latitude. This decrease was probably due to the sucrose being utilized for growth and fruit formation. From August 25 through November 25 there was a very large increase of sucrose, the value in November being over ten times higher than in August. These sugars that earlier in the season were evidently being broken down and utilized for fruit and vine growth were accumulating probably as a result of fruit maturity and a decrease in rate of vine growth.

Instead of a decline in concentration, as in the case of sucrose, the reducing sugars showed a decided increase in concentration during the first month. After the June 25th sampling, the reducing sugars decreased until October 26. From that date to November 25 there was a decided increase. Although the reducing sugars were in larger concentrations than sucrose, the variations were not as pronounced. The maximum concentration (in June) was only about 100 per cent higher than the minimum concentration (in October).

As shown in Table I, the starch content of the residues increased with the season, while the acid hydrolyzable fraction remained constant.

TABLE I—Polysaccharides in Extracted Residues, Dry Basis

Sampling Date	Starch (Per Cent)	Acid Hydrolyzable Substances in Terms of Glucose (Per Cent)
May 25	0.32	16.53
June 25	0.58	15.45
July 27	1.58	16.09
August 25	—	17.08
September 25	2.31	17.72
November 25	2.53	17.69

Conclusions

Both sucrose and reducing sugar values found in Hunt muscadine shoots decreased rapidly during early summer and attained their former or higher values by late fall. The starch values showed a general increase from May through November, while the acid hydrolyzable fraction remained constant.

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A Preliminary Study of Chlorosis in American Grapes[1]

By L. R. Bryant and George A. Beach, *Colorado Experiment Station, Fort Collins, Colo.*

CHLOROSIS of the "iron-deficiency" type is one of the soil problems common in growing many varieties of American grapes in semi-arid areas of the United States and elsewhere. There appear to be no means of predicting resistance or susceptibility to this trouble except by trial. The data presented are part of a study of grape variety adaptation in progress at the Colorado Experiment Station at Fort Collins, Colorado. In 1935 five plants each of 42 varieties of American grapes were set out on a Fort Collins fine sandy loam soil. The pH of soil samples at a 1 to 2 ratio (soil to water) gave values of 8.2 in the 0- to 6-inch level and 8.5 at 18 inches below the surface. The calcium carbonate content of the soil ranged from 1.5 per cent in the upper 6 inches to 11.75 per cent at 18 inches. The total soluble salts as estimated from an electric bridge test were 0.07 per cent in the upper 6 inches and 0.08 per cent at 18 inches.

In 1937, during the third season in the vineyard, some indications of chlorosis began to appear, enough being indicated to show the desirability of specific study of this phase of the grape production problem. Beginning in 1938, annual chlorosis readings have been made on this material. Diagnostic "dip tests" (1) for deficiencies of various elements on foliage have shown consistent results only from the use of iron salts, indicating that the chlorosis is of the "iron-deficiency" type.

The summary of resistance or susceptibility of each of the 42 varieties to this type of chlorosis over a 3-year period follows. The varieties in each group are arranged in the order of increasing severity.

Group 1. Resistant or Chlorosis-Free:—All foliage is green and growth is vigorous. Varieties—Beta, Brighton, Delaware, Eaton, Elvira, Herbert, Portland, Salem, and Urbana.

Group 2. Very Light Chlorosis:—A part of the new growth shows some chlorosis, but total plant growth is vigorous. Varieties—Agawam, Bacchus, Barry, Clinton, Caco, Daisy, King, Wilder, Winchell, Goethe, and Vergennes.

Group 3. Light Chlorosis:—Chlorosis extends to most of the newer leaves and to some of the older. Usually there is a slight decrease in plant vigor. Varieties—Champion, Ontario, Lindley, and Wyoming.

Group 4. Medium Chlorosis:—A definite yellowing is evident over most of the plant which still retains fair vigor. Varieties—Fredonia, Sheridan, Concord, Niagara, Regal, Ives, Catawba, Moyer, Hubbard, Campbell Early, Worden, and Gaertner.

Group 5. Severe Chlorosis:—The plant is seriously chlorotic with definite impairment of growth. Varieties—Moore Early, Diamond, and Lucile.

Group 6. Very Severe Chlorosis:—The plants are severely chlorotic

[1]Published as Paper No. 117 of the Scientific Journal Series, Colorado Experiment Station.

with growth seriously impaired. "Foliage burning" is evident on at least part of the leaves. Varieties—Champagne, Pocklington, and Lutie.

In some respects these data do not always check with those reported elsewhere. For example, the varieties Bacchus, Clinton and Elvira, which are classed in the resistant or the very light chlorosis groups here, have all been reported as sensitive to calcareous soils (2). Under the conditions considered in this test, the growth of all three has been satisfactory to date.

On the criterion of severity of chlorosis as shown by the data presented, varieties in group 1 appear to be well adapted to the average soils in this area. Those in group 2 should also be satisfactory. Varieties in groups 3 and 4 must be considered questionable, but some of the varieties are well worth further trial. Those in groups 5 and 6 definitely are not worth planting here.

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Studies on the Shatter of Grapes with Special Reference to the Use of Solutions of Naphthalene Acetic Acid to Prevent It

By W. T. Pentzer, *U. S. Department of Agriculture, Fresno, Calif.*

SOME varieties of grapes, notably Sultanina of the vinifera varieties, "shatter" or pull loose from the bunches during handling and shipment. The reports of Gardner, Marth, and Batjer (2, 3) on the inhibition of the normal dropping of mature apple fruits by spraying the trees just prior to fruit maturity with dilute solutions of plant growth substances prompted the trial of one of these materials to prevent such shattering of grapes.

Methods and Materials

Six varieties of grapes, Sultanina, Tokay, Ribier, Emperor (*Vitis vinifera* varieties), Pierce (*V. Labrusca* variety), and James (*V. rotundifolia* variety) were treated with solutions of naphthalene acetic acid. Some of the grapes of the Sultanina and James varieties were slightly overmature and were ready to shatter when they were treated. Pierce and Tokay were likewise very ripe but they showed little tendency to shatter, whereas the late season varieties, Ribier and Emperor were in a firm mature condition.

The solutions of naphthalene acetic acid were applied to the fruit in two different ways. In one set of experiments, freshly picked grapes were soaked in dilute solutions of the chemical for 5 minutes. In other cases it was applied as a spray to the grapes 6 days prior to harvest. The concentration for these tests was 0.005 per cent, the solution being acidified by the addition of 0.5 grams of citric acid per liter. The fruit treated after harvest in 1939 was held for 24 hours after treatment at 55 to 75 degrees F, temperatures considered favorable for response from the chemical. It was then given the usual fumigation with sulphur dioxide that commercial treatments receive and was held at 38 to 40 degrees for 12 days before inspection, to simulate shipment to eastern markets. The fruit that was sprayed on the vines was handled in a similar manner after it was picked. The experiments conducted in 1940 were designed to test the chemical under conditions most favorable for response. The grapes were not fumigated with sulphur dioxide after they were soaked in the chemical nor were they held at refrigerator car temperatures. They were stored at 65 to 75 degrees until they were examined 4 to 6 days after the treatment.

After the above holding periods, the force required to pull untreated and treated grapes from their pedicels was measured. The method followed was similar to that of De Villiers (1), a spring balance sensitive to 10 grams being used for this purpose. The sample from each lot consisted of 100 or more berries for all but the James variety of which the amount of fruit available was limited. With the Sultanina variety in 1939, measurements were made on 360 berries selected in lots of 20 from 18 bunches in the untreated lot, and on 460 berries

selected from 23 bunches in the treated lot. The fruit used in all the tests was picked from the same vines and was segregated into lots of uniform appearance before treatment. The significance of differences between the means of treated and untreated lots was tested by the F value, using the variance of the means of bunches within the lots as the estimate of error.

Results

The differences found in the mean attachment of treated and untreated lots (Table I) were so small that no significance could be attached to them. There was greater variance between bunches of the same lot than there was between treated and untreated lots. Ribier was a doubtful exception with F meeting the 5 per cent but not the 1 per cent requirement of significance.

The failure of the growth-promoting chemical, naphthalene acetic acid, to increase the adherence of grape berries to the pedicel as contrasted with the success that attended its use to retard the fall drop of apples can probably be best explained by a consideration of the morphological differences in the attachment of the two kinds of fruit. In none of the Vinifera varieties was there an indication that an abscission layer was formed across the pedicel resulting in a weakened attachment such as occurs with apples and pears. The Pierce variety (*Labrusca*) had an abscission layer formed close to the point of attachment with the berry in some cases but rarely did the pedicel break at this point. Instead, the "brush" or network of vascular tissue which enters the grape through the pedicel pulled out of the fruit, this variety behaving the same as the Vinifera varieties in this respect. The James variety (Rotundifolia) pulled loose at an abscission layer, leaving some of the pedicel attached to the grape. If the action of the chemical is one involving the cells of an abscission zone, no response could be expected in the Vinifera varieties. With varieties of Labrusca and of Rotundifolia, there is basis for expecting some effect, although none was observed in these limited tests.

The larger grapes as determined by weight, were more strongly attached than smaller ones of the same variety (Table II), a relationship previously reported by De Villiers (1). The comparative size of the conducting tissue which forms the attachment may account for the differences noted. However there are factors other than size that influence pedicel attachment within the variety. Jacob (4) has shown that girdling increased berry adherence even though it did not increase the size of the berries when done at the beginning of bloom. Also, he found that the largest berries were obtained by girdling after the fruit had set, whereas the strongest adherence was obtained by girdling earlier, at the end of bloom. The maturity of the fruit has a marked effect on berry attachment, a fact well recognized by growers and shippers. A prolonged storage period also apparently weakens the attachment. The shatter of grapes of the Ribier variety, commonly having a very strong attachment when harvested, was observed last season after about three months storage.

Changes in the composition of the fruit which result in softening of the flesh and lessened resistance to shearing forces, usually attribu-

TABLE I—THE EFFECT OF NAPHTHALENE ACETIC ACID ON THE PEDICEL ATTACHMENT OF CERTAIN GRAPE VARIETIES

Variety	No Treatment			Naphthalene Acetic Acid			
	Size of Sample		(A) Mean Attachment (Grams)	Size of Sample		(B) Mean Attachment (Grams)	Difference B–A (Grams)
	Bunches	Grapes		Bunches	Grapes		
			Treated After Harvest				
Sultanina*...	18	360	170	23	460	163	-7
Sultanina...	5	100	160	5	100	175	+15
James......	4	36	189	4	40	180	-9
Pierce......	5	100	192	5	100	205	+13
Pierce......	5	100	250	5	100	247	-3
Tokay......	5	100	397	—	—	—	—
Ribier*.....	34	170	599	35	175	564	+35
Emperor....	5	100	664	5	100	644	-20
			Sprayed On The Vine				
Sultanina*...	20	400	203	12	240	185	-18

*Tests made in 1939, all others in 1940.

TABLE II—THE RELATION OF GRAPE SIZE TO STRENGTH OF PEDICEL ATTACHMENT IN SULTANINA GRAPES

Lot	Mean Weight of 20 Berries In The Lot (Grams)	Mean Attachment (Grams)
A..................................	43.7	179
A..................................	56.0	222
B..................................	37.4	135
B..................................	45.6	166
B..................................	57.2	197

ted to alterations in the pectic constituents in the cell walls, are probably involved in the weakening effect of overmaturity or prolonged storage.

A marked difference was noted between the varieties in berry attachment. The good storage varieties, such as Ribier and Emperor, characterized by tough skin and well developed pedicels, had pedicel attachments three to four times as strong as Sultanina.

SUMMARY

Naphthalene acetic acid when applied in a preharvest spray or as a dip to freshly picked grapes failed to increase berry adherence significantly in any of the varieties tested, which included four Vinifera varieties and one each of Labrusca and Rotundifolia.

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Periclinal and Total Polyploidy in Cranberries Induced by Colchicine

By HAIG DERMEN and HENRY F. BAIN, *U. S. Horticultural Station, Beltsville, Md.*

SEEDLINGS of cranberry were grown aseptically in test tubes of agar. When about 1½ inches long and having three to six true leaves, the seedlings were removed and wrapped in bundles of 25 each in wet absorbent cotton (root-ends covered, stem-ends exposed) and the latter rolled to form plugs that would fit loosely in 1-inch vials. The bundle of plants was then inverted and placed in the vials with the stems submerged in aqueous solutions of colchicine of 0.05, 0.10, and 0.20 per cent, respectively, for 24 hours. One bundle was dipped in a vial containing water as a check. A few months after treatment all these seedlings were examined by using stoma size as a criterion for polyploidy. Polyploidy was rare in the 0.05 per cent treated plants. The plants treated with 0.2 per cent solution contained more polyploidy than those with 0.1 per cent. Cytological preparations were made from growing branch tips by the paraffin method. It was clearly revealed that branches that had shortened internodes, slow habit of growth, and leaves changed in shape as well as in thickness were totally polyploid, while in those that had a normal habit of growth, whose leaves looked like those on a normal branch but had large stomata, polyploidy was confined to the epidermis. We have observed some branches that have a growth and other habits suggesting total polyploidy, but stomata of the leaves were normal. No critical cytological examinations have been made of such material, but we suspect that this might be a case of diploid epidermis and polyploid inner tissue. This kind of formation was found in peach material reported in this Volume. Such a visual difference in the treated material may assist in selecting out types of polyploidy where stoma size is used as a method of detecting polyploidy. Six commercial varieties were treated by applying drops of glycerine-colchicine solution on the tips of growing shoots as described by the senior author in the Botanical Review 6: 599–635, 1940. On five of these varieties (Centennial, Mammoth, McFarlin, Prolific, and Vose's Pride), polyploidy effect was discovered by stomatal examination.

Further Chromosome Studies of Some Varieties of Blackberries

By H. E. FISCHER,[1] GEO. M. DARROW, and G. F. WALDO,
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IN THE genus Rubus, the entire raspberry group (*Idaeobatus* sub-genus), except for a few tetraploid varieties of the red raspberry,[2] has been found by previous workers to be diploid, all species thus far examined having possessed 14 chromosomes. Rosanova (7) has reported that the high mountain form of *Rubus idaeus* L. in Siberia is tetraploid. On the other hand, the blackberries and dewberries have been found to be strikingly variable with regard to chromosome number (5, 8). The species studied had chromosome numbers varying from 14 to 84, and were in multiples of 7, indicating an extremely high degree of polyploidy in the Eubatus sub-genus of the genus Rubus. Since the chromosome number of blackberries is so variable and species hybridization is of common occurrence, it was considered important to determine the chromosome number of commercial varieties and of selections of the western wild trailing blackberry so that these could be used intelligently in the breeding program. Most of the material used in this study was obtained from the Pacific Coast States and was supplied by G. F. Waldo. The chromosome numbers determined are summarized in Table I.

In this study of chromosome numbers it is noteworthy that five selections from the wild blackberries in northwestern California and western Oregon and Washington were hexaploid, eight (including Ideal) were octoploid, and three were 12-ploid. Darrow and Longley (2) reported two native hexaploids, two native octoploids (also the variety Ideal), one native decaploid, and four native dodecaploids. Crane (1) has reported obtaining an octoploid from seed sent to him from California.

Rubus species having odd numbers of genoms have been found in nature by Longley (5) and Darrow and Longley (2) who have observed both triploids and pentaploids. Gustafson (3, 4) also reports that the European apomictic *Eubati veri* were triploid, tetraploid and pentaploid, whereas the species group, *Rubi corylifolii,* was found to have tetraploid, pentaploid, hexaploid, superhexaploid (± 45) and heptaploid species.

In the present study two recently named varieties, Pacific and Cascade, have been obtained by crossing one of the dodecaploids with the Logan (6n), and were found to be nonaploid. Since these unbalanced types were fertile enough to be considered likely commercial varieties, it appears that in the higher polyploids the degree of unbalance due to the extra sets of chromosomes resulting in gametes with varied chromosome numbers does not always appreciably affect the fertility. Steril-

[1]Temporary appointment.

[2]Rosanova (7) has reported some wild autotetraploid forms of *Rubus idaeus* from Siberia. However, we have found the native *R. strigosus* Mchx. of similar type from Mt. Mitchell, North Carolina, to be diploid. Longley and Darrow (6) also reported triploid and tetraploid cultivated red raspberries.

TABLE I—CHROMOSOME NUMBERS IN BLACKBERRIES (THOSE LISTED AS "NATIVE" FROM VARIOUS SOURCES ARE SELECTIONS OF THE WILD TRAILING BLACKBERRY OF THE PACIFIC COAST, *R. Macropetalus* DOUG. AND RELATED SPECIES)

	Number of Chromosomes		Stage at Which Chromosome Number was Determined
	Somatic Number*	Gametic Number**	
A. Diploid-Blackberry			
1. Early Harvest (*R. floridus* Tratt.)	—	7	Met. II
B. Pentaploid			
2. Oregon No. 157 (Logan ×Himalaya)	35	—	—
C. Hexaploid			
3. Boysen	42	—	—
4. Logan	—	21	Met. II
5. Native-Arcata, Calif.	—	21	Dk., Met. II
6. Native-Westport, Calif.	—	21	Dk., Met. II
7. Native-Rohnerville, Calif.	—	21	Dk., Met. II
8. Native-Agate Beach, Calif.	42	21	
9. (Logan ×Lucretia)	—	21	Met. II
10. (Himalaya ×Austin Thornless)	—	21	
11. Native-Starr, Ore.	—	? 21	Met. I, II
D. Heptaploid			
12. Oregon No. 73 (Logan & Austin Thornless)	49	24, 25	Late proph. II*
E. Octoploid			
13. Native-Elk Creek, Calif.	—	? 28	Met. I, II
14. Native selection-Ware, Wash.	—	? 28	Dk., Met. II
15. Native selection-named Ideal, Ore.	56	28	Met. II
16. Native-Elmer Johnson, Ore.	—	28	Diakinesis
17. Native-Point Arena, Calif.	56	—	
18. Native-Bodega Bay, Calif.	56	28	Diakinesis
19. Native-Fort Ross, Calif.	—	—	Met. II
20. Native-Branstetter, Calif.	—	28	Ana. II
F. Nonaploid			
21. Pacific (Zielinski ×Logan)	63	31, 32	Telo. II
22. Cascade (Zielinski ×Logan)	—	31, 32	—
G. Dodecaploid			
23. Native selection, Zielinski, Ore.	84	—	—
24. Native selection-named Cazadero, Ore.	84	—	—
25. Native-Hunter, Ore.	84	—	—

*Mitotic metaphase from root-tip sections.
**From microsporocyte metaphase I and II.
Notes. 7. Occasional chromatic elimination. 9. Occasional micronuclei at quartet stage. 10. Lagging of univalents at anaphase I. 12. Occasional lagging in I and II—mostly bivalent formation. 14. 1–2 univalents—At Met. II, occasional microcytes. 15. Occasional microcyte. 16. Occasional chromosome elimination. 19. Dyads and occasional microcytes. 21. Regular meioses, occasional univalents.

ity in the higher polyploids is usually considered to be due to the meiotic irregularities resulting from the pairing of more than two chromosomes with consequent irregular chromosome distribution to the gametes. However, it is apparent that in the higher polyploids where the gametes possess more than one set of chromosomes, the addition or loss of one or even more chromosomes would not be likely to create a sufficient degree of unbalance in the gametes to result in their abortion.

Another factor which is undoubtedly of great importance as a cause of sterility in the higher polyploids (particularly species hybrids) is the partial or complete failure of chromosome association between the genoms contributed by the parents resulting in considerable meiotic irregularities and gametic abortion.

TABLE II—CROSSES INVOLVING VARIETIES WITH DIFFERENT CHROMOSOME NUMBERS WITH THE NUMBER OF SELECTIONS FROM EACH (CORVALLIS, OREGON)

Number of Genoms	Cross	Number of Selections
5n (4n ×6n)	Himalaya ×Young	1
5n (6n ×4n)	Logan ×Evergreen	3
5n (6n ×4n)	Logan ×Himalaya	1
6n (8n ×4n)	Ideal ×Himalaya	1
7n (6n ×8n)	Logan ×Ideal	11
7n (6n ×8n)	Logan ×Austin Thornless	8
7n (8n ×6n)	Ideal ×Young	1
$\frac{15n}{2}$ (6n ×9n)	Logan ×123 (Zielinski ×Logan)	1
$\frac{15n}{2}$ (9n ×6n)	(Zielinski ×Logan) ×Logan	4
$\frac{15n}{2}$ (9n ×6n)	(Zielinski ×Logan) ×Boysen	2
9n (?) (6n ×12n, prob.)	Logan ×wild	2
9n (12n ×6n)	Zielinski ×Young	8
9n (12n ×6n)	Zielinski ×Logan	77
10n (12n ×8n)	Zielinski ×Austin Thornless	1

Fertility in a species hybrid would be expected, especially if the chromosomes tend to associate in pairs, either the genoms of one species pairing with those of the other parent species (allosynapsis — AB, A^1B^1) or the genoms from each parent species pairing separately among themselves (autosynapsis — AA^1, BB^1). This would perhaps explain the fact that meiosis in the nonaploids, Pacific and Cascade, was found to be remarkably regular, only occasional univalents and microcytes being observed.

In the cooperative breeding work at Corvallis, Oregon, in the eight years, 1932–1939, some 124 selections from crosses involving plants with different chromosome numbers have been made, as shown in Table II. All except two of these selections may be expected to have odd chromosome numbers in their egg and pollen cells, yet they were productive enough to have been selected for further testing. Five selections were pentaploid, one hexaploid, 20 heptaploid, seven were $\frac{15n}{2}$, 87 were nonaploid, and one was decaploid. These data provide further evidence that an extra set of chromosomes may be of relatively little importance as a contributory factor in producing sterility in allopolyploid species hybrids.

In the breeding of Rubus, a knowledge of chromosome numbers and genom relationships is important mainly in facilitating the determination of the crosses that would be most likely to succeed when the purpose is to combine desirable characters of one variety or species with those of other species. Due to chromosome (and genic) duplication, inheritance in the higher polyploids is, for the most part, quantitative in character. Therefore, in breeding work, the aim is to introduce as many genoms carrying the most desired characteristics as possible into a hybrid. In species hybrids the ratio of genoms with most preferred genes to those with less desirable factors must be considered. An unfavorable ratio of desired to undesired genes is likely to affect the degree of dominance of the former in the progeny.

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Production, Berry Size, and Growth of Red Raspberries As Influenced by Mulching[1]

By W. H. Childs, *West Virginia Agricultural Experiment Station, Morgantown, W. Va.*

RASPBERRY plantings in West Virginia are often on sites that are steep enough to erode considerably when they are cultivated. Also the size of the crop is distinctly limited in many years by a deficiency of water during the picking season. It would be highly desirable if some system of soil management could be used which would decrease or eliminate soil erosion and conserve moisture at the same time. The use of a straw mulch seemed to be the most logical means of meeting these requirements. An experiment with red raspberries was laid out, therefore, in the spring of 1934 to compare a mulch with clean cultivation plus a cover crop.

The site selected on the Horticultural Farm at Morgantown comprised approximately ⅓-acre and sloped gently to the north. The soil was a Tilsit silty clay loam, which is considered one of the poorer soil series in West Virginia. Surface drainage was good, but a mottling of the subsoil noted in nearby trenches indicated that internal drainage was poor at certain seasons of the year.

The area was divided into 36 50-foot plots. Three varieties — Latham, Newburgh, and Chief — were distributed at random over the area so that there were 12 plots of each variety. While preparing the ground in April, 1934, superphosphate and muriate of potash were worked into the soil at the rates of 300 pounds and 100 pounds per acre respectively. The plants were set 3 feet apart in rows 8 feet apart. All plants received a light application of sodium nitrate shortly after they were set. Fertilization was uniform throughout the planting for the duration of the experiment and consisted of a single application of sodium nitrate made in April each year, 200 pounds per acre in 1935, and 300 pounds per acre in 1936, 1937, and 1938. This quantity of fertilizer was found desirable in a previous experiment on the same farm (1).

During 1934 and 1935 the entire area was cultivated until early September, when a rye cover-crop was planted. In 1936 cultivation was continued until August. Differential treatments were then begun. There was some inequality of stand among the various blocks in 1935; hence the yields were disregarded. By the spring of 1936, however, a full stand was obtained, and the yield records for that year were used as a basis for pairing plots for subsequent studies. This method of pairing is superior to random pairing without yield records, since it decreases the error resulting from inherent soil differences. The total yield for the six plots of each variety which were to be mulched was very close to that for the plots which were to be cultivated, as shown in Table I. Sufficient mulch was applied to the "mulched" plots in August, 1936, to prevent practically all weed growth. This mulch was

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TABLE I—THE EFFECT OF MULCH ON YIELD AND WOOD PRODUCTION OF RED RASPBERRIES*

Treatment	Yield							Wood Production				Correlation Between Yield and Wood Production by Varieties	
	Quarts Per Acre Basis			Odds in Favor of Mulch†		Average Number of Berries Per 670 Grams		Pounds of Post Harvest Pruning Per Acre		Odds in Favor of Mulch			
	1936	1937	1938	1937	1938	1937	1938	1937	1938	1937	1938	1937	1938
Latham													
Mulch.....	2,448	7,308	5,382	8:1	490:1	308.3	335.7	5389.2	2890.8	15:1	2199:1	0.395 ±0.1643	0.875 ±0.0456
Cultivated	2,466	6,624	4,158			341.1	326.5	4523.4	1769.4				
Chief													
Mulch	1,296	4,266	4,050	28:1	11:1	462.1	489.6	3069.0	2169.0	14:1	118:1	0.790 ±0.0732	0.945 ±0.0228
Cultivated	1,260	3,708	3,420			514.5	499.7	2626.2	1393.2				
Newburgh													
Mulch	3,132	6,750	—	118:1	—	299.0	—	3978.0	—	5:1	—	0.822 ±0.0692	—
Cultivated	3,168	5,076	—			328.9	—	3225.6	—				
Viking													
Mulch	—	5,652	1,368	—	—	451.3	521.3	4235.4	1335.6	—	—	—	—
Cultivated	—	4,590	1,062			489.9	513.7	3972.6	820.8				

*Six 50-foot plots for each treatment for each variety excepting Viking.
†Odds calculated on basis of increase over 1936 yields.

replenished in April of the succeeding years as necessary to maintain a heavy covering. Rye, wheat, and buckwheat straws were used, and the entire area between rows was mulched. The cultivated plots were treated as before.

At the same time that this planting was made, a 1/9-acre adjoining area was set to Viking red raspberries. Fertilization was the same as already described. This entire planting, six 100-foot rows, was mulched in the spring of 1935. When differential treatments were begun in August, 1936, it was decided to include this variety; therefore the mulch was removed from half of the planting, and cultivation was begun. There was undoubtedly some loss of roots, since there is a tendency for the development of a large number of fibrous roots near the soil surface under a mulch, as noted by Havis (4) and Clark (2).

During 1937 and 1938 records were taken of yields, number of berries in 670 grams (approximately 1 quart) for each treatment of each variety at each picking, and weight of post-harvest prunings. The data on yields and wood production could be analyzed according to Student's Method for Latham, Chief, and Newburgh, but not for Viking. In the spring of 1938, which was quite wet, parts of several blocks of Newburgh were killed by what appeared to be a rootrot; hence records of yields for this variety in 1938 were valueless. This trouble was so widespread throughout the planting by the spring of 1939 that the experiment was discontinued.

Results and Discussion

Tables I and II summarize the data obtained in these studies. The total yields indicate that the use of a mulch increased production for all varieties tested, both in 1937 and 1938. The increases were not as great as were obtained by Darrow and Magness (3), but it should be noted that yields are high for the cultivated plots, whereas those reported by Darrow and Magness were quite low. Clark (2) and Havis (5) report yield increases of similar magnitude to those obtained by the author. It is probable that still greater differences would have been obtained in this experiment if both 1937 and 1938 had not been "wet" years. The total precipitation from January 1, 1937 to August 1, 1938 was almost 12 inches greater than normal, much of this coming just before or during the harvest period with 12.40 inches of rainfall for May and June, 1937 and 12.50 inches for these same months in 1938 as contrasted with a normal of 7.94 inches.

Statistical analysis of the yield records indicates that the increases obtained for Newburgh in 1937 and for Latham in 1938 were distinctly significant, those for Chief in 1937 were doubtfully significant, and those for Latham in 1937 and Chief in 1938 were not significant. The relatively light yields for Viking in 1938 were the result of considerable winter killing of this variety during the winter of 1937–38.

Berry size and wood production data indicate that mulching may increase yields in two ways. When the mulch was applied in August, 1936, quite a large portion of the fruiting wood for 1937 had already been formed. As a result, although more wood was produced by the mulched plots than by the cultivated ones, the increase was not very great for 1937 and was not significant for any variety. For the 1937

TABLE II—THE EFFECT OF MULCH ON YIELD DISTRIBUTION OF RED RASPBERRIES, EXPRESSED AS PER CENT OF TOTAL YIELD HARVESTED AT EACH PICKING

Treatment	Picking Number																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Latham—1937																			
Mulch	—	0.08	0.08	0.31	1.40	3.27	11.84	13.53	10.27	15.94	11.07	7.32	9.78	4.85	3.82	4.25	2.19	—	—
Cultivated	—	0.05	0.10	0.36	1.46	2.70	11.68	11.70	11.47	15.02	11.11	7.92	11.60	4.54	4.06	4.01	2.21	—	—
Chief—1937																			
Mulch	0.91	2.56	2.93	7.14	10.93	10.44	17.22	9.63	8.50	10.66	8.19	4.91	3.86	1.15	0.57	0.31	0.10	—	—
Cultivated	0.97	2.91	3.39	8.06	11.62	9.22	18.22	8.37	8.93	11.30	8.17	3.93	3.71	0.71	0.34	0.11	0.05	—	—
Newburgh—1937																			
Mulch	—	0.40	0.94	3.80	7.96	9.63	14.91	13.37	8.41	10.14	8.98	4.90	6.77	3.07	2.53	2.98	1.21	—	—
Cultivated	—	0.43	1.20	4.83	8.47	9.27	15.13	11.34	9.26	8.92	10.54	5.39	6.40	3.07	2.57	2.49	0.71	—	—
Viking—1937																			
Mulch	—	—	0.09	0.35	0.72	2.07	11.04	15.52	14.41	15.41	10.96	9.22	10.55	3.90	2.56	2.49	0.71	—	—
Cultivated	—	—	0.17	0.45	0.93	1.66	10.25	14.16	11.59	16.17	10.49	8.01	12.66	4.83	3.82	3.68	1.12	—	—
Latham—1938																			
Mulch	—	—	—	0.09	0.40	1.06	3.12	8.28	12.94	14.43	8.99	16.73	10.65	10.84	4.36	3.10	2.66	1.79	0.56
Cultivated	—	—	—	0.13	0.69	1.73	4.20	9.69	13.82	14.32	8.13	16.06	10.04	9.56	3.92	2.52	2.75	1.81	0.62
Chief—1938																			
Mulch	0.13	0.21	0.55	1.53	4.55	7.37	11.78	15.37	16.88	12.67	6.85	9.22	5.85	5.51	1.54	0.74	0.29	—	—
Cultivated	0.52	0.94	1.13	2.79	6.99	9.54	12.96	17.41	14.15	14.13	4.26	6.91	3.36	3.09	1.03	0.57	0.22	—	—
Viking—1938																			
Mulch	0.08	0.25	0.21	0.78	0.89	4.22	9.26	12.25	13.12	15.61	10.07	15.72	7.21	6.07	2.33	1.21	0.71	—	—
Cultivated	0.22	0.32	0.33	1.36	1.23	5.07	8.20	8.84	16.94	13.80	7.75	18.15	5.87	6.40	2.94	1.80	1.30	—	—

picking season, then, it appears that, since there was not a greatly increased production of wood, the individual berries had more moisture available and were about 10 per cent larger. This increased size was at least partially responsible for the increase in yields.

In 1938, on the other hand, wood production was significantly greater for the mulched plots than for the cultivated ones, and the berries were approximately the same size, being slightly smaller for Latham and Viking and slightly larger for Chief when the plants were mulched. In this case the increased yields were distinctly associated with increased wood production, as shown by the coefficients of correlation given in Table I. Although actual measurements were not made, qualitative observation showed that the increased amount of wood in the mulched plots was a result both of a greater number of canes and of larger canes.

According to the data in Table II, the use of a mulch tends to retard ripening somewhat, as indicated by the fact that a slightly smaller percentage of the total crop was obtained during the early part of the harvest period. This was particularly noticeable in 1938, but was true for all varieties in both seasons. The differences in ripening, however, were not of sufficient importance to deter anyone from using a mulch, since the actual yields were as great for the mulched plots as for the cultivated ones after the first two or three small pickings.

Summary and Conclusions

The use of a mulch in a red raspberry planting of Latham, Chief, Viking, and Newburgh, at Morgantown, West Virginia, was found to be superior to cultivation as evaluated either by total yields or by wood production. The increased yield was shown to be statistically significant in two cases out of five, doubtfully significant in a third, and not significant in the other two. Wood production, as measured by the weight of post-harvest prunings, was shown to be highly correlated with yield in most instances. An increase in berry size was partially responsible for the increased yield of the mulched plots in 1937 but not in 1938. Mulching was found to delay ripening slightly, but not to such an extent as to influence a grower against using this method of soil management.

Where the cost of mulching materials is not excessive, the use of a mulch instead of cultivation in a red raspberry planting may be found profitable under conditions similar to those of this experiment. This is likely to be especially true where the planting is located on a site that is subject to erosion, or where moisture conservation is important.

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Mulch	0.91	2.56	2.93	7.14	10.93	10.44	17.22	9.63	8.50	10.66	8.19	4.91	3.86	1.15	0.57	0.31	0.10	—	—
Cultivated	0.97	2.91	3.39	8.06	11.62	9.22	18.22	8.37	8.93	11.30	8.17	3.93	3.71	0.71	0.34	0.11	0.05	—	—
Newburgh—1937																			
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Cultivated	—	—	—	0.13	0.69	1.73	4.20	9.69	13.82	14.32	8.13	16.06	10.04	9.56	3.92	2.52	2.75	1.81	0.62
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Cultivated	0.52	0.94	1.13	2.79	6.99	9.54	12.96	17.41	14.15	14.13	4.26	6.91	3.36	3.09	1.03	0.57	0.22	—	—
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Cultivated	0.22	0.32	0.33	1.36	1.23	5.07	8.20	8.84	16.94	13.80	7.75	18.15	5.87	6.40	2.94	1.80	1.30	—	—

picking season, then, it appears that, since there was not a greatly increased production of wood, the individual berries had more moisture available and were about 10 per cent larger. This increased size was at least partially responsible for the increase in yields.

In 1938, on the other hand, wood production was significantly greater for the mulched plots than for the cultivated ones, and the berries were approximately the same size, being slightly smaller for Latham and Viking and slightly larger for Chief when the plants were mulched. In this case the increased yields were distinctly associated with increased wood production, as shown by the coefficients of correlation given in Table I. Although actual measurements were not made, qualitative observation showed that the increased amount of wood in the mulched plots was a result both of a greater number of canes and of larger canes.

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Where the cost of mulching materials is not excessive, the use of a mulch instead of cultivation in a red raspberry planting may be found profitable under conditions similar to those of this experiment. This is likely to be especially true where the planting is located on a site that is subject to erosion, or where moisture conservation is important.

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The Rocky Mountain Strawberry as a Source of Hardiness

By A. C. Hildreth and LeRoy Powers, *Horticultural Field Station, Cheyenne, Wyo.*

THE Central Great Plains and the high valleys and plateaus of the adjacent Rocky Mountain region present difficult conditions for strawberry growing. Winters are dry and windy, and temperatures of minus 30 to 40 degrees F may occur with little or no snow cover to protect plants. Moreover, in the prevailing alkaline soils many varieties develop chlorosis which seems further to decrease their cold resistance. No commercial variety is reliably hardy in this region.

Since 1932, the Horticultural Field Station at Cheyenne, Wyoming has been making collections of native Rocky Mountain strawberries as a possible source of hardiness. Their true value was not realized until the severe winter of 1935–36 when collected native plants were undamaged while all of the 150-odd commercial varieties in our trials were killed or badly injured. These native strawberries occur in canyons and on slopes of the foothills and the mountains up to about 12,000 feet elevation. In winter these sites are mostly covered with snow several feet in depth. Strangely enough, with such protection, the extreme hardiness to cold which these wild strawberries possess would seem to be quite unnecessary for survival in their native environment.

In 1936 systematic collections of Rocky Mountain strawberries were begun in order to assemble the various types for study and for selection as parental material. In all, about 42,000 plants have now been collected representing more than 1,100 localities in Wyoming, Colorado, Montana, New Mexico, and Utah. These collections are now under cultivation in our trial plots at Cheyenne. None of these native selections is suitable for commercial culture chiefly because of the small fruits. Although the berries are generally of high quality, the frequently expressed opinion that all wild strawberries are of good flavor is decidedly not true. As grown in our trial plots, these native plants show extreme variations in horticultural characters, differing in size, shape, color, and quality of fruit and in season of maturity, fruiting habit, prolificacy, tendency to produce runners, resistance to disease, and tolerance of soil alkalinity. Some are distinctly everbearing while others are June bearers. Some show considerable drought resistance and all thus far have proved winter hardy without protection at Cheyenne, Wyoming.

While the taxonomy of these native strawberries still appears to be somewhat confused, those in our collection seem to be generally of the type *Fragaria cuneifolia* Nutt. A few collections are obviously *F. vesca* L. which, in general, seems less promising horticulturally than *F. cuneifolia,* and has therefore not been used in our breeding work.

During the winter of 1937–38 three commercial varieties, Gem, Dorsett, and Fairfax, were crossed with three different collections of the native strawberry, *Fragaria cuneifolia.* Observations on the char-

acteristics of these F_1 plants and comparisons of these with commercial varieties and with their native parents may be of interest to strawberry breeders.

In general the F_1 plants were considerably superior to Gem, Dorsett, and Fairfax in their ability to survive the winters of 1938–39 and 1939–40 in the breeding plots at the Cheyenne Horticultural Field Station. Over 60 per cent of the Dorsett and Fairfax plants and approximately 30 per cent of the plants of Gem were winter killed; whereas there was no appreciable winter killing among the plants of the F_1 generation nor among the native plants. In most cases where plants of the commercial varieties did survive the winter, the crowns were badly injured. Such injury was not discernible in either the F_1 plants or the native plants.

As regards the ability to produce runners, the F_1 plants and the native selections used as parents are greatly superior to the three commercial varieties. However, there is considerable variation in respect to this character among the F_1 plants. A few of the F_1 plants produce no more runner plants than the commercial varieties. On the whole, however, the F_1 plants fall somewhere between the native plants and the commercial varieties in tendency to form runners.

The comparison of the fruits of the F_1 plants with the parental varieties is particularly interesting. The F_1 plants show a great range in fruit size. Some have berries rather closely approaching the size of Fairfax; whereas other plants of this generation produce berries as small as the smaller fruits of the native parent. In the majority of cases, however, fruits of the F_1 plants were somewhat larger than those of the native collections, but were considerably smaller than those of the commercial varieties. The greatest diversity between F_1 crosses involving Gem, Dorsett, and Fairfax was found in flavor and sweetness. The crosses involving Fairfax and Dorsett were decidedly superior to those crosses involving Gem. In fact, among the Gem crosses no plants were found having fruits that could be classified as high in quality. On an average the fruits from Fairfax crosses were somewhat superior in sweetness and flavor to the fruits from F_1 plants in which Dorsett was a parent. A number of the F_1 plants having either Fairfax or Dorsett as one parent produced fruits that were decidedly superior in sweetness and flavor to fruits of either of these varieties. One plant from the F_1 generation of native x Fairfax produced fruits which in addition to being sweet and having good flavor were very highly aromatic.

Attention should be called to the variation between F_1 plants as regards prolificacy, time of flowering and maturing of fruit. On the whole, the F_1 plants of none of the crosses were outstanding as regards the number of fruits produced per plant. Nevertheless, a few exceptional F_1 plants were found to be more prolific than Gem, which at the Cheyenne Horticultural Field Station is more prolific than either Dorsett or Fairfax. In season of flowering and fruiting, it was found that the F_1 plants in general were not earlier than the parents, but in a few cases F_1 plants bloomed and ripened fruits earlier than either the native or commercial parents. F_1 plants with both June-bearing and

everbearing habit were obtained from the crosses involving Dorsett and Fairfax as well as from the crosses involving Gem.

The F_1 generation plants exhibited considerable variation as to shape and color of fruit; position of fruits on the plants; type of flower cluster; shape, size, and abundance of leaves; and habit of plant growth. The shape of fruit varied from oblate to decidedly elongated. Plants having fruits constricted at the calyx end were rather common. The fruits on different F_1 plants varied in color from deep red to very pale red or what even might be classified as light pink. The position of the fruits on the plant varied from close to the crown, with fruits well covered by leaves, to the ends of long flower stalks well above the foliage.

The F_1 hybrids set seed readily when self-pollinated, back-crossed to either parent, or crossed with other F_1 hybrids. The seeds germinated and in most cases produced vigorous plants. With the great diversity of characters, it should be possible, from the segregates of these crosses between the cultivated strawberry and the wild Rocky Mountain types, to select varieties adapted to withstand the severe winters and other climatic conditions of the Rocky Mountain and Central Great Plains Regions of the United States. Also, the opportunity should not be overlooked for improving the cultivated strawberries in earliness, ability to runner, prolificacy, and sweetness, flavor, and aroma of fruit by using *Fragaria cuneifolia* in crosses.

The Pattern of Strawberry Root Development Under the Matted and Thinned Row

By A. L. Schrader, *University of Maryland, College Park, Md.*

IN CONNECTION with growth and fruiting studies of the Blakemore strawberry, previously reported (2), in which thinned rows with the runner plants spaced 7 and 11 inches apart were shown to be highly superior in fruitfulness to the usual matted row of similar width, some effort was made to determine the root distribution and concentration under the two systems of culture. It was hoped that such a study might add to our knowledge of the rooting of strawberries and to aid in the interpretation of differences in growth and fruiting under thinned and matted rows. In order to make such determinations on a quantitative basis, it was necessary to devise a means of root removal from definite soil zones. This was accomplished by taking as units of study 3-inch cubes of soil, removed in the following manner from the soil zones: First, an area was marked off accurately to include 24 inches of the width of the row and 18 inches in the direction of the row. The plants in this area were counted and each plant was located as to position in this area (Fig. 1). After removal of the tops, the bare soil was marked off in 3-inch squares in checkerboard style, and likewise, a perpendicular face of this soil block, exposed with a spade by digging 12 inches deep and 24 inches wide, was also marked off in 3-inch squares. Following the marked lines, it was possible to cut into the soil block with a heavy 16-inch meat knife and remove 3-inch cubes of soil in a systematic manner as shown in Fig. 1. The Sassafras sandy loam in which these plots were located was especially well adapted to this method, and is a soil commonly used for strawberry production in Maryland.

For the removal of roots from the soil cubes, it was found that by breaking up the soil cube and screening carefully through a 16-mesh screen, the roots could be separated almost entirely from the soil. It was found highly undesirable to allow roots and soil to dry before screening, as the fine roots break into many little pieces that pass through the screen. The fresh roots were strong enough to hold together with very little loss in the screening process. After thorough drying, the small amount of soil left with the roots after screening was easily separated from the roots with a small brush.

Each block of soil 18 by 24 by 12 inches contained 292 of the 3-inch cubes and nine such blocks of soil were taken at each of three sampling dates. On September 5, 1935, in the fall of the first season, the first sampling consisted of three blocks of soil under the matted row, three blocks under the 7-inch spacing and three blocks under the 11-inch spacing. Similar sets of samples were taken from the same rows of these treatments on April 7, 1936, a month before fruiting and on June 10–11, 1936, after fruiting. Dry weights were obtained of the roots in each individual 3-inch cube.

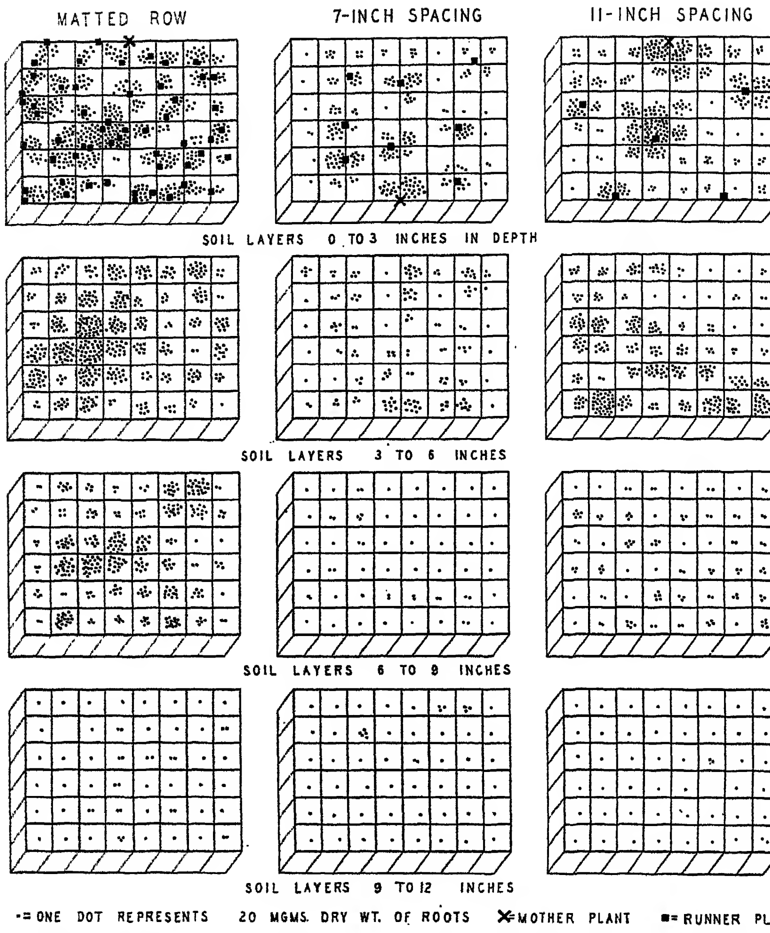

FIG. 1. Diagram of root distribution and amount of roots in 3-inch layers of soil to a depth of 12 inches under matted row and spaced plants of strawberries, as determined on September 10, 1935, in the first season, following spring planting.

RESULTS

In order to diagram the blocks of soil and to show distribution of roots within such blocks, Figs. 1 and 2 were prepared by using the data from one typical block from each of the sampling dates of September, 1935, and April, 1936. Each block of soil is represented by four layers, namely, 0 to 3 inches, 3 to 6 inches, 6 to 9 inches, and 9 to 12 inches of the soil depth. These figures show several interesting points. First, a great increase in root development occurred during the fall, winter, and early spring months between September 10, 1935, and April 7, 1936. Also, it can be noted that more roots developed

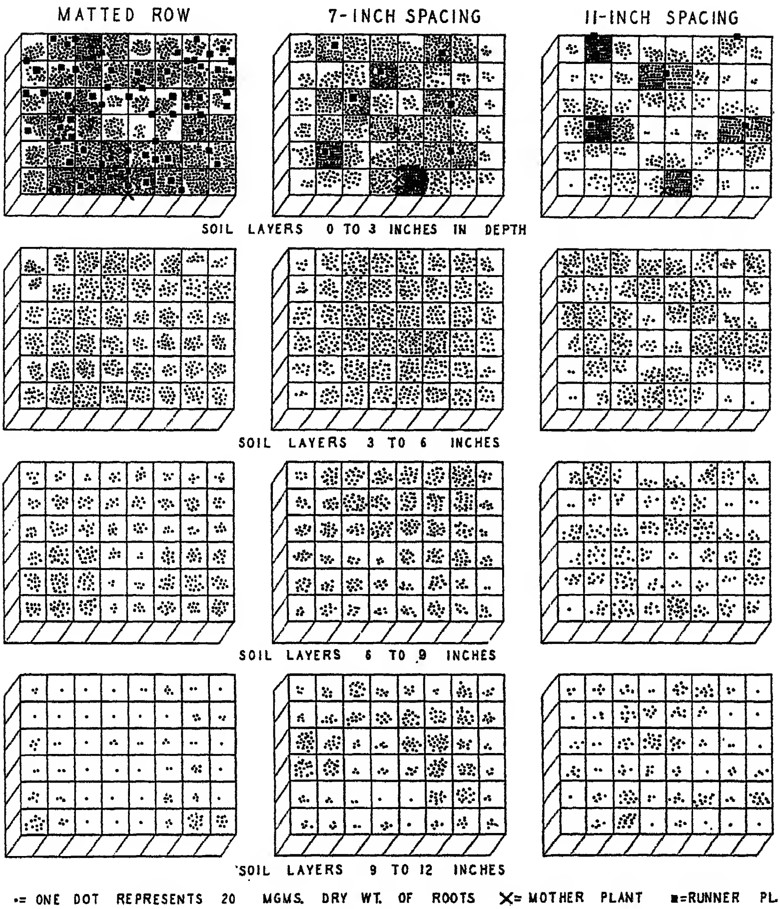

FIG. 2. Diagram of root distribution and amount of roots on April 5, 1936, under similar matted rows and spaced plants, shown in Fig. 1. These samples were taken about 1 month before fruiting.

during this period in the lower layers of soil under the spaced plants than under the matted row plants. A large part of this root development occurred in the fall months, as shown by other studies (3) near these plots. This difference may partially account for the greater drouth resistance of thinned rows, as previously reported in this experiment (2).

The largest concentration of roots occurs in the upper 0- to 3-inch layer of soil and is more concentrated in the regions of greatest plant population in the matted row, as well as in the immediate region of the spaced plant. This pattern follows into the lower layers of soil as well. It is surprising to note that the 11-inch spacing of plants failed to utilize the entire 0- to 3-inch soil zone for root development. The

TABLE I—DRY WEIGHT OF STRAWBERRY ROOTS UNDER MATTED ROW AND SPACED ROWS (EACH WEIGHT FIGURE REPRESENTS THE TOTAL GRAMS OF ROOTS IN A SOIL LAYER 18 BY 24 INCHES)

Depth of Soil (Inches)	Weight of Roots (Grams)			Per Cent of Roots		
	Matted Row	7 Inch Spacing	11 Inch Spacing	Matted Row	7 Inch Spacing	11 Inch Spacing
September 10, 1935						
0 to 3	116.0	59.2	81.0	48.0	60.0	36.6
3 to 6	69.4	28.1	79.6	28.5	26.0	35.9
6 to 9	42.1	8.6	53.7	17.5	8.0	24.3
9 to 12	15.1	5.7	7.1	6.0	5.0	3.2
April 17, 1936						
0 to 3	433.4	250.3	178.1	59.5	42.1	42.3
3 to 6	186.9	186.5	137.6	25.5	31.4	31.0
6 to 9	87.4	91.7	77.5	11.9	15.4	17.4
9 to 12	23.1	67.3	40.8	3.1	11.1	9.3

much heavier development of roots under the matted row is felt to be a big factor in more rapid utilization of available soil moisture, which, in turn, would adversely affect fruit size, at least in certain seasons.

The pattern of root development in June 1936, following the harvest is not presented but is similar to the April pattern except for the development of more roots.

A summation of the root weights in the four soil zones of the entire samplings is given in Table I. These results on the matted rows are similar to those reported by Ball and Mann (1). However, few roots were found below 12 inches in depth. With the thinned or spaced rows, again the data show a greater percentage of roots in the low.r soil layers under the spaced plants than under the matted row plants.

CONCLUSION

Dry weights of roots, obtained from 3-inch cubes of soil throughout four soil layers to a depth of 12 inches, showed that matted rows of Blakemore strawberries developed more roots, especially in the upper soil layers than spaced plants, and spaced plants 7 inches and 11 inches apart did not fill the entire soil zone between plants, but did develop a greater percentage of roots in the lower soil layers than did matted row plants. The greater root development of matted row plants before fruiting may be at least partially responsible for the smaller fruit size under the crowded matted row that Blakemore develops, compared to the larger fruit size from thinned rows.

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Relationship of Width of Thinned Row to Productiveness and Quality in the Blakemore Strawberry[1]

By JULIAN C. CRANE and I. C. HAUT, *University of Maryland, College Park, Md.*

THINNING (spacing) of strawberry plants has been recently introduced to strawberry growers as a means of improving size and quality, as well as yield of berries, especially with those varieties which are prolific plant producers. This paper presents the results of studies started in the spring of 1939, to determine the most desirable width of row to attain highest yield, size, and quality of the fruit, with the Blakemore variety when thinned to a distance of 4 to 6 inches between plants. An application of a 3–12–6 fertilizer was made at the rate of 350 pounds per acre 1 week previous to planting and no additional fertilizer was applied. In all plots, the mother plants were set 18 inches apart in a single row on a well drained Sassafras sandy loam soil on April 10, at College Park, Maryland.

The thinning treatment was maintained on three rows each of 10-inch, 20-inch, 30-inch, and 40-inch widths with five plot replications of each treatment making a total of 15 rows for each width. A 10-inch aisle separated rows within treatments and also between rows of different treatments within the plots. Thinning of daughter plants was accomplished by a procedure which, it was thought, approached one of several commercially feasible methods using machine power. Runners were allowed to root during July and August. About the middle of September the beds were raked cross-wise of the rows and the excess runners were pulled into the space between the rows. A circular edger was then used to cut these runners back to the desired width of row. Following this procedure, the rows were inspected and occasionally additional plants were removed by hand in order that the desired density of stand remained.

Cultivating operations, like those commercially practiced, were the same for all the rows throughout the season, and weeding was done by hand when necessary. About the middle of November, a 6-inch layer of rye straw mulch was applied to the plots and the following spring it was raked into the aisles and amounts in excess were removed. After growth had started, the plants in each row were counted to determine the stand of plants in the row. A rainfall of 1.93 inches fell on May 20, 1 week before harvest, and a ½ inch on May 30. From then on no more rain fell during harvest. Toward the latter part of the picking season the plants showed evidence of moisture deficiency as indicated by wilting and browning of the leaves.

Harvesting began May 27, pickings being made approximately every 2 days until June 17 when the season ended. As soon as the berries were picked they were taken to the field house where they were graded into U. S. No. 1's and culls, weighed, and then counted. The weights of the berries were converted to quarts by taking the mean weights

[1]Scientific Contribution No. 531, Department of Horticulture, Maryland Agricultural Experiment Station.

throughout the season of several quart baskets and fractionating this factor when it was necessary to convert fractions of quarts.

Results and Discussion

The data are presented in Table I. On the basis of yield alone, a decrease in width of row resulted in increased yields per acre. The 10-inch rows produced significantly higher total yields as well as U. S. No. 1 berries, than either the 20-inch, 30-inch, or 40-inch rows. The

TABLE I—Relationship of Width of Thinned Row to Acre Yields of the Blakemore Strawberry, 1940 (Space Between Rows 10 Inches)

Width of Thinned Row (Inches)	Total Yield Per Acre (Quarts)	Yield Per Acre U.S. 1 (Quarts)	Per Cent U.S. 1's of Total Yield	Per Cent Yield Decrease From 10-Inch Row	No. U.S. 1 Berries Per Quart	Average Distance Between Plants (Inches)
10	15,635	12,169	77	—	98	4.3
20	13,997	10,571	75	13	103	5.2
30	12,148	9,243	76	24	103	5.6
40	10,632	8,163	76	33	101	6.2

Difference necessary for significance:
1 per cent level 1,476 1,392.
5 per cent level 1,107 1,044.

percentage of U. S. No. 1 berries of the total yield was not modified to any great extent by differences in width of row except that the 10-inch rows produced about 1.5 per cent more U. S. No. 1 berries than did the other width rows. However, as the width of row increased, a progressive decrease in yield per acre resulted as shown by a decrease of 13 per cent for the 20-inch rows, 24 per cent for the 30-inch rows, and 33 per cent for the 40-inch rows. The difference in yields between each successive treatment was found, by analysis of variance, to be highly significant.

Upon the determination of stand of plants, it was found that, with the method employed, unequal spacing of plants resulted; the average distance between plants being 4.3 inches on the 10-inch rows and progressively increasing up to 6.2 inches on the 40-inch rows. This variation in distance among plants was due, primarily, to the difficulty in getting a sufficient density of runners to the outer limits of the wider rows. However, the results of all previous spacing work indicate that little, if any, difference in unit yields can be expected between distances of 4 and 6 inches. Moreover, this difficulty would attend any method of plant thinning by field implements (*i.e.*, for example, a hay rake used in combination with a modified disk harrow); hence, remains a consideration in determining the most desirable width of row to maintain under commercial conditions.

Although the plants in the 10-inch rows were closer together they outyielded, on a plant basis, the plants in the wider rows which had a greater distance between plants. This can be explained by the fact that the narrow rows are, very largely, composed of the earliest formed and established runner plants, whereas the wider rows contain an increasingly larger percentage of late formed runner plants having a much decreased fruiting capacity as established by several workers.

Also, the percentage of total plants receiving the benefits of the border effect, as regards additional moisture and nutrients, becomes increasingly smaller as the width of row increases.

In conclusion, the data obtained in this study suggest that with varieties, such as Blakemore, which produce excessive runner plants, greater yields from a thinning practice can be obtained when the width of row is kept sufficiently narrow to insure a high proportion of early formed runner plants. Such is the case, it is believed, with a 10-inch width row, where the width of row to be maintained is formed early in the season from early formed runner plants, thereby obtaining a much higher percentage of plants with a high fruiting capacity.

Present tools employed in the vegetable industry for narrow row crops can be adapted to strawberry culture to satisfactorily handle a narrower distance between rows.

The Rooting Response of Various Species of Rubus to Conventional Methods of Propagation

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ASIDE from that pertaining to horticultural species commonly grown for their fruits, little collected information is available on the propagation of Rubus. Recent tendencies in breeding have aroused interest in species not in cultivation, and emphasized need of information concerning their propagation. Propagators frequently receive material in condition unsuited to conventional methods, so they, as well as pathologists, must frequently use special techniques. For this reason it has seemed worth while to place on record the experience obtained with the rather large number of Rubus introductions received and grown by the Division of Plant Exploration and Introduction at Glenn Dale, Maryland. In view of the confused condition of taxonomy of Rubus, identification of some items reported here is only provisional; for this reason the Plant Introduction number is published with the species name.

Most of the material covered in this report has been grown both out-of-doors and under glass. Observations began in 1937 with recording of cases of suckering and of tip-layering. In subsequent years quantitative data have been kept on results with propagation in the greenhouse, almost invariably in lots of 20 to 25 cuttings and usually with several repetitions. Propagations with leaf-buds and stem cuttings were made largely during the months of July to November inclusive, using material ranging in maturity from herbaceous to semi-hardwood. Root pieces obtained around November 1 from field grown plants constituted the single trial with root cuttings. Since season and condition of plant exercise much influence on results, the data are compared here mostly on the basis of the best results secured in any single trial, rather than on averages, which would be meaningless unless the work were done on a scale not practicable in this case. As reported in Table I, "good" generally signified 65 to 100 per cent rooting; "fair" 33 to 64 per cent; "poor" 1 to 32 per cent.

Propagation by herbaceous and semi-hardwood stem cuttings, which is conventional with many plants, is not common in practical propagation of Rubus, though its feasibility with this genus has been noted on several occasions, Carrière (1) Fuller, (2) Mottet, (3). Where tip-layering or root cuttings give good results, this method is obviously unimportant commercially. For establishing disease-free foundation stocks, grown in a protected space, however, it may be very useful. As indicated by the data in Table I, this method of propagation offers little difficulty; the range in ripeness of material that produces roots is indicated by the fact that several cuttings can generally be used from a single axis. Green tips from material grown under glass may be used; green tips from outdoor grown material have given poor results, but riper tips from outdoors have frequently given good results. Practically all of the stem cuttings supplying the data used here have been rooted

TABLE I—TESTS OF PROPAGATION METHODS WITH A NUMBER OF RUBUS SPECIES PRESENTED IN TERMS OF BEST RESPONSE†

P.I. No.	Species	Source	Propagate by			
			Cuttings			Tip Layering
			Stem	Leaf Bud	Root	
	A: Raspberry and Raspberry-Like					
99705	*R. lasiostylus* Focke	Roumania	G†	G	—	G
101459	*R. crataegifolius* Bge.	U.S.S.R.	O	P	G	O
113695	*R. crataegifolius* Bge.	U.S.S.R.	O	—	—	O
104862	*R. fraxinifolius* Poir.	England	F	P	G	O
111079	*R. ellipticus* J. E. Sm.	India	F	F	—	O
115011	*R. ellipticus* J. E. Sm.	Ceylon	G	F	F	P
112041	*R. glaucus* Benth.	Java	G	G	—	G
113696	*R. idaeus* L.	Manchuria	O	O	P*	O
113811	*R. ampelinus* Focke	China	G	G	O	G
114789	*R. ampelinus* Focke	China	G	F	O	G
113812	*R. Buergeri* Miq.	China	G	—	—	G
116149	*R. Buergeri* Miq.	China	G	G	—	G
113816	*R. Lambertianus* Ser.	China	G	G	O	G
116150	*R. Lambertianus* Ser.	China	G	G	O	G
113817	*R. mesogaeus* Focke	China	P	O	—	O
114792	*R. mesogaeus* Focke	China	O	O	F	P
113821	*R. tephrodes* Hance	China	G	G	O	G
116151	*R. tephrodes* Hance	China	G	G	P	G
114310	*R. parviflorus* Nutt.	Mexico	P	O*	G	O
114793	*R. setchuenensis* Bur. & Fr.	China	G	G	O	G
115008	*R. sp. aff. R. niveus* Thunb.	India	G	G	O	G
115012	*R. sp. aff. R. niveus* Thunb.	Ceylon	G	G	P	G
118077	*R. sp. aff. R. niveus* Thunb.	India	F	G	G	G
122202	*R. sp. aff. R. niveus* Thunb.	India	G	G	—	G
117511	*R. phoenicolasius* Maxim.	China	P	P	G	G
136135	*R. biflorus* Buch.-Ham.	England	G	G	—	G
136137	*R. flagelliflorus* Focke	England	P	P	—	—
136138	*R. Cockburnianus* Hemsl.	England	F	G	—	—
136140	*R. leucodermis* Torr. & Gray	England	G	G	—	G
137503	*R. Henryi* Hemsl. & O. Ktze.	England	F	G	—	—
	B: Blackberry and Dewberry					
105162	*R. Linkianus* Ser.	Sweden	G	G	G	G
113865	*R. Linkianus* Ser.	U.S.S.R.	F	G	F	G
113818	*R. sp. aff. R. Linkianus* Ser.	China	P	G	G	P
113855	*R. ulmifolius* Schott	U.S.S.R.	F	P	—	G
118080	*R. ulmifolius* Schott	India	F	G	G	G
113856	*R. caesius* L.	U.S.S.R.	G	F	G	G
113858	*R. caesius* L.	U.S.S.R.	G	G	G	G
113861	*R. caucasicus* Focke	U.S.S.R.	G	G	P	G
131862	*R. affinis* Weihe & Nees	England	F	G	—	G
131863	*R. plicatus* Weihe & Nees	England	P	—	—	G
131864	*R. cissburiensis* W. Bart & Riddelsd.	England	G	F	—	G
131865	*R. hirtus* Waldst. & Kit.	England	G	P	—	G
131866	*R. infestus* Weihe	England	G	F	—	—
131867	*R. nitidioides* W. Wats. var. "Merton's Early"	England	G	—	—	—
131868	*R. rhombifolius* Weihe	England	G	—	—	—
131869	*R. rosaceus* Weihe & Nees	England	G	—	—	—
131871	*R. Schlechtendahlii* Weihe	England	F	G	—	G
131872	*R. thyrsiflorus* Weihe & Nees	England	G	G	—	—
131873	*R. thyrsiger* Banning & Focke	England	G	G	—	—
136148	*R. thyrsoideus* Wimm.	England	G	G	—	—

*Limited trial.
†G = good, 65 to 100 per cent rooting; F = fair, 33 to 64 per cent; P = poor, 1 to 32 per cent; O = none; —no observation.

in closed cases, with very little watering; a few tests in open benches with cheese-cloth covering over the cuttings have yielded promising results.

Of the raspberry species listed, only *Rubus crataegifolius* Bge., *R. fraxinifolius* Poir., *R. idaeus* L., *R. mesogaeus* Focke, and *R. parviflorus* Nutt. have multiplied by suckers and these are the species that

TABLE II—THE NUMBER OF RUBUS SPECIES ROOTING BY VARIOUS METHODS ARRANGED IN RELATIONSHIP TO THEIR FREEDOM OF ROOTING BY LEAF-BUD CUTTINGS

Leaf-bud Cuttings	Stem Cuttings				Tip Layers				Root Cuttings				Suckers			
	G	F	P	O	G	F	P	O	G	F	P	O	G	F	P	O
								Raspberry Types								
Good	10	2	—	—	9	—	—	—	—	—	2	3	—	—	—	4
Fair	1	—	—	—	—	—	1	—	—	1	—	—	—	—	—	—
Poor	—	1	2	1	1	—	—	2	4	—	—	—	2	—	—	1
None	—	—	2	1	—	—	—	3	1	1	1	—	2	1	—	—
								Blackberry Types								
Good	6	5	—	—	7	—	1	—	4	1	1	—	2	—	—	—
Fair	3	—	1	—	2	—	—	—	1	—	—	—	—	—	—	—
Poor	1	1	—	—	2	—	—	—	—	—	—	—	—	—	—	—
None	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

have been the most difficult to propagate by leaf-bud or stem cuttings, or by tip rooting. On the other hand most of the species which tip rooted easily have propagated readily by leaf-bud and stem cuttings. This comparison suggests that those raspberry species which propagate by suckers propagate poorly, if at all, from the canes. This is best shown by Table II, which presents the relationships of the results secured by the different propagating methods. The data presented here give added confirmation to an observation by Thomas (4) that those species which tip layer also propagate readily by leaf-bud cuttings, but in addition they suggest that this generalization likewise includes stem cuttings. Whether this entire relationship holds for the blackberries cannot be stated since only *R. caucasicus* Focke and *R. sp. aff. R. Linkianus* Ser. have produced suckers.

From the propagator's standpoint, *Rubus Buergeri* Miq. an herbaceous form with a slender, trailing, vine-like cane is especially interesting because it roots so freely wherever its canes touch the ground and because cuttings from all parts of its cane produce roots. The form identified as *R. phoenicolasius* Maxim. though rooting poorly from leaf-bud and stem cuttings, roots very freely at the tips and also occasionally at the nodes.

Only limited trials have been made with a few root-inducing substances. In most cases, stimulation has been greatest on those species that root without treatment. Applied as a dust in talc to a few cuttings of a large number of species, indole butyric acid apparently increased rooting in a few cases but had a retarding effect with definite injury in others. In other trials a 1–1000 dust of three parts naphthalene acetic acid plus one part each of thiorurea and nicotinic acid gave increased rooting on one species but had no effect on another.

Many of the species reported here were introduced as seed. Of these original introductions the following gave excellent germination without acid or stratification treatments: *Rubus ellipticus* J.E. Sm., *R. Lambertianus* Ser., *R. mesogaeus, R. sp. aff. R. niveus* Thunb. and *R. tephrodes* Hance. Under similar conditions R. parviflorus germinated poorly while *R. setchuenensis* Bur. and Fr. and *R. phoenicolasius* gave fair germination, although results with the latter were measurably

better with stratification for three months. In addition good germination of *R. caesius* L., *R. caucasicus* and *R. crataegifolius* seeds was obtained after stratification for 42 days while *R. sp. aff. R. Linkianus* seeds were slow and irregular in germinating.

The names applied to the species used in the present study are those under which the species are carried in the inventory of the Division of Plant Exploration and Introduction.

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The Effect of Time of Mulching on the Cold Resistance of Strawberry Plants[1] [2]

By W. G. Brierley and R. H. Landon, *University of Minnesota, St. Paul, Minn.*

WITHIN the past few years Minnesota strawberry growers in accord with recent recommendations, have changed from the old practice of late mulching to the practice of applying the winter mulch earlier in the fall. They have hoped thereby to avoid the low temperature injury that so commonly accompanied the old practice of mulching after the soil had frozen. In this attempt to escape injury they frequently have mulched their fields even before the plants have been exposed to frost. Growers who have practiced this very early mulching have reported more severe losses than occurred under the old practice of late mulching. As a result of these losses, they have expressed some doubt as to the value of early mulching.

When attempting to determine the cause of these losses, one is led to believe that the practice of early mulching may be, in part at least, responsible for the failure of strawberry plants in the field to develop the maximum degree of hardiness. It has been shown by Angelo (1) and Steele, Waldo, and Brown (2) that the strawberry plant has the ability to harden, *i.e.* endure greater cold than otherwise, if exposed to temperatures near or slightly below freezing before being subjected to the minimum temperature that this species of plant can withstand. These workers also have shown that cold resistance in strawberry plants is acquired in light but not in darkness, that a greater degree of hardiness develops in dry soil, and that hardiness is gained by exposure to temperatures that range from slightly above to slightly below freezing. For these reasons it may be suspected that early mulching tends to prevent the development of cold resistance since it darkens the plants, conserves soil moisture, and protects against the temperatures necessary for hardening.

In the fall of 1939 an investigation was undertaken at the University Farm, St. Paul, Minnesota, for the purpose of determining the effect of time of mulching on the cold resistance of strawberry plants. Plants of the Beaver variety were dug late in September and potted in medium loam soil in 5-inch pots after selection for uniformity in size and condition. The pots were then placed in open frames where they were exposed to outdoor conditions. Watering was limited to the amount needed to keep the soil from drying out. At the beginning of the mulching treatments the plants were divided into six lots, none of which contained less than 100 pots. Mulching was done by covering the plants with 3 inches of straw. Beginning October 7 one lot was covered each week until all had been mulched. The occurrence

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[2]Completion of certain parts of this paper was made possible by personnel of the Works Projects Administration Official Project 65-1-71-140, Subproject No. 408. Sponsor: University of Minnesota.

of freezing temperatures, in Centigrade, from shortly before the first lot was covered until the completion of mulching follow:

Before October 7:- September 25, –2 degrees; September 30, –3.5 degrees.

October 7 to 14:- October 14, –4 degrees.

October 15 to 21:- October 16, –5 degrees; October 17, –4.5 degrees.

October 22 to 28:- October 27, –2 degrees; October 28, –6.5 degrees.

October 29 to November 4:- October 30, –3.5 degrees; November 2, –5 degrees; November 3, –6.5 degrees; November 4, –4.5 degrees.

November 5 to 11:- November 5, –1 degree; November 6, –3 degrees; November 8, –3.5 degrees; November 10, –8 degrees; November 11, –8 degrees.

The dates of mulching are shown in Table I.

TABLE I—GROWTH RESPONSE AFTER EXPOSURE TO FREEZING TREATMENTS OF BEAVER STRAWBERRY PLANTS MULCHED AT WEEKLY INTERVALS (POTTED PLANTS, 10 POTS PER LOT)

Date of Mulching	Freezing Dates and Temperatures								
	Nov 21, –3 Degrees C			Nov 22, –6 Degrees C			Nov 23, –9 Degrees C		
	Number of Plants			Number of Plants			Number of Plants		
	Vigorous	Weak	Dead	Vigorous	Weak	Dead	Vigorous	Weak	Dead
Oct 7.......	0	0	10	0	0	10	0	0	10
Oct 14......	5	2	3	4	4	2	0	2	8
Oct 21......	10	0	0	9	0	1	0	5	5
Oct 28......	10	0	0	9	0	1	2	6	3
Nov 4......	9	1	0	9	1	0	9	0	1
Nov 11.....	7	3	0	8	2	0	6	3	1

On November 21, which was 10 days after the last lot was mulched, 10-pot samples selected at random were taken from each of the six lots and frozen at a controlled temperature of –3 degrees C for 24 hours. Other samples were taken the next two days and frozen at –6 and –9 degrees C for the same length of time. Upon removal from the freezing chamber, the pots were placed in a cellar held at 5 degrees C for 1 week, during which time they thawed out completely. They were then placed beneath a bench in a greenhouse where they were held at 10 degrees C for a week. At the end of this time the pots were placed on a bench in a greenhouse held at 20 to 25 degrees C until the final data were taken on the growth response of the plants.

An examination of the lots at the time the samples were taken for freezing showed that almost all of the plants covered October 7 had produced one or two etiolated leaves. The plants covered October 14 also had produced new leaves in many instances. These leaves were considerably less etiolated than those of the plants covered October 7. The last lot to show any evidence of growth under the mulch was the lot covered October 21 where a slight crown development without etiolation was noted.

The growth response of the samples taken from the lots is shown in Table I. It will be seen that all plants in the sample taken from the

lot mulched October 7 were killed by freezing at –3 degrees C. This temperature is about that of a light frost in the field. If any hardening resulted from the frosts of September 25 and 30, it was apparently lost during a week of warm weather that preceded the time of mulching. The fact that the plants mulched October 7 were killed at –3 degrees C seems to indicate that they did not harden under the straw cover.

When growth response (Table I) is considered in relation to the occurrence of frost, it will be seen that plants in the later lots, subjected for a sufficient length of time to conditions conducive to the development of hardiness, were able to survive exposure to the temperatures used in this study. Plants in the two lots mulched on October 7 and October 14, lacking sufficient exposure to conditions promoting hardening were killed or severely injured at the temperatures used. Exposure to hardening conditions for even as short a time as 1 week may be important since the sample from the lot covered October 7 was completely killed at –3 degrees C, while that from the lot mulched October 14 showed 70 per cent survival. Under the conditions of the experiment, the plants mulched November 4 showed the greatest resistance to injury at the lowest temperature used. This temperature, –9 degrees C, is close to the minimum degree of cold that strawberry plants of hardy varieties hardened under optimum conditions are likely to withstand. The plants mulched November 11 showed somewhat greater injury although only one plant was killed at –9 degrees C. This indicates that there is a time when further delay in mulching may be responsible for increased winter injury. This result is in agreement with earlier studies of cold resistance in strawberry plants.

Despite the fact that early mulching is generally recommended for the northern part of the United States, the data obtained from this study indicate that if strawberry plants are covered too early, they are not likely to harden properly and severe losses may occur. While it is too much to expect that mulching can always be done at exactly the right time, it is evident that the plants should be exposed to several early season frosts before being covered in order to lessen the likelihood of extensive low temperature injury.

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Fall Setting Strawberries in Missouri[1]

By A. D. Hibbard and T. J. Talbert, *University of Missouri, Columbia, Mo.*

SUMMER drought is the limiting factor in strawberry production throughout the Ozark region. The industry there is established around the Aroma variety; a mediocre plant producer, and unfortunately very sensitive to moisture deficiency, especially on soils low in organic matter.

In the early years, when virgin land was readily available, summer drought was not a factor in securing a good row. Profitable production is difficult at present on fields that have been under cultivation long enough to destroy most of the organic matter and deplete the supply of available plant nutrients.

It is generally known that the strawberry grows more rapidly during the cooler seasons of the year. It is possible that a cultural system for southern Missouri can be developed which would permit the plants to make a better use of the favorable seasons.

Strawberry plants set in the spring frequently do not have time to become established and start runner production before the summer drought begins. A fall set plant has more time to become established. Therefore, it is ready to start growth with the first warm days of spring. Spring planting must be delayed until the ground becomes dry enough to work. Many years of experience have taught the producers to make their plantings as early in the spring as possible if a good row and maximum yields are to be secured. During recent years, dry weather has come so early that even the very earliest spring set plants have failed to make a good row except on virgin soil. A few growers have reported favorable results from fall setting. The practice has not gained much popularity owing to the additional labor involved in mulching and early spring cultivation. In fall setting, the grower generally experiences better weather than that prevalent in spring, for the work of preparing the ground and transplanting. Experiments were started in the Ozark region in 1937 to determine if the apparent advantages were great enough to justify the additional costs involved.

At Monett, experimental settings are made in late October and continued at 15 day intervals until December. Winter weather conditions usually prevent further setting before mid-February. Settings are made at 2 week intervals in the spring, with the last around April 15, which is usually the latest date that a good row can be secured in a favorable season. All plants set during the fall are mulched with a light covering of wheat straw to prevent heaving.

Records are made about July 1 of the number of original plants that are alive, leaves per plant, crown divisions and runners produced, and runner plants rooted. In mid-October, counts are made on the final survival of mother plants and the number of established runner plants. The stand and plant production are calculated from these data. A plot

[1]Contribution from the Department of Horticulture, Missouri Agricultural Experiment Station Journal Series No. 717.

is given a stand rating of 100 per cent when there is a matted row 2 feet wide with an average plant spacing of 8 inches. A satisfactory stand was secured only during the season of 1940. Yield measurements the following spring complete the records. The experimental layout consists of triplicate blocks of one-hundredth acre plots.

Results so far are of a preliminary nature. They have been so favorable to fall setting, however, that a progress report is of interest at this time. The growing seasons during which these experiments have been in progress were characterized by three distinct types of summer drought: a severe midsummer drought in 1938, a fall drought in 1939, and a short June drought this year. The season of 1940 was more favorable for the development of a good row than any other season during the last 10 years.

Table I shows the growth and row resulting from setting at different dates. These data are comparable to those from trials during the two previous years, except that there was a greater loss of mother plants from the spring settings during those years.

TABLE I—Comparative Growth of Spring and Fall Set Strawberry Plants During the 1940 Season of Ample Rainfall

Setting Date	Growth by July 15				Final Growth October 15		
	Leaves Per Plant	Double Crowns (Per Cent)	Runners Per Plant	Rooted Runners Per Plant	Living Mother Plants (Per Cent)	Plants Per Mother	Stand (Per Cent)
Fall							
Nov 1	8.1	43	4.0	3.3	78.4	23.5	131.5
Nov 15	9.4	57	6.1	3.3	86.6	21.5	133.7
Dec 2	10.6	57	6.1	5.1	85.6	23.2	143.0
Spring							
Feb 15	9.0	45	5.7	2.7	76.7	20.6	113.7
Mar 1	7.1	57	4.4	2.5	83	21.5	126.7
Mar 15	8.7	60	4.9	2.6	80	17.5	98.4
Apr 1	7.3	40	4.9	2.7	92	14.4	85.3
Apr 15	6.4	29	2.7	1.5	86	13.5	75.3

During each year the fall settings could be distinguished after July because of the greater runner production. At the end of each season these plots had a better stand since more of the original plants were alive and more runner plants had been produced. Also, since the fall settings start runner production earlier in the season, the new plants were larger the following fall. In each of the years the stand was about 25 per cent better on the fall set plots. Very early fall setting or very late spring setting was not as desirable as later in the fall or earlier in the spring. There was less difference between the rows secured from different fall setting dates than between those produced by transplanting at different times in the spring. The spring settings seemed to be influenced more by environmental factors at the time of planting.

A summary of the growth made by setting on the most favorable fall date, November 15, compared with the most favorable spring date, March 15, is made in Table II.

TABLE II—FAVORABLE RESPONSE OF AROMA STRAWBERRIES TO FALL SETTING IN THE MISSOURI OZARK REGION (GROWTH MEASUREMENTS ARE AVERAGES FOR TRIPLICATE PLOTS FOR THREE YEARS; YIELD FOR TWO SEASONS ONLY)

Setting Date	Growth by July 15				Final Growth October 15			Yield Quarts Per Acre
	Leaves Per Plant	Double Crowns (Per Cent)	Runners Per Plant	Rooted Runners Per Plant	Living Mother Plants (Per Cent)	Plants Per Mother	Stand (Per Cent)	
Fall								
Nov 15	7.7	44.5	5.2	3.0	74.6	16.4	90.1	755
Spring								
Mar 15	6.5	27.5	4.3	2.1	63.6	12.8	60.8	212
Difference in favor of fall setting	1.2	17.0	0.9	0.9	11.0	3.6	29.3	543

The growth data cover three seasons, while the yields are for two only. Yields are low since summer droughts interfered with plant production both years. During each of the three seasons there was an increase in early growth and stand from fall setting. These results cannot be considered as conclusive, since the work has not been carried over a sufficient number of years. Weather conditions were such, during the period of the experiment, that fall setting of the Aroma variety was a practice which produced a superior row. The returns from the increased yield justified the additional costs incurred through mulching and extra cultivation. It is apparent that fall setting will be of greatest value during those years when summer droughts limit growth and plant production.

Botanical and Economic Distribution of Vaccinium L. in Maine

By F. B. CHANDLER, *Maine Agricultural Experiment Station*, and FAY HYLAND, *University of Maine, Orono, Me.*

TEN of the 130 species of *Vaccinium* L. are found in Maine and, of these, eight are of some economic importance. This report attempts to outline the distribution of the species as a whole and only mentions a few of the botanical varieties. Stations in Maine where identified specimens have been collected have been plotted on maps and the general economic areas have been outlined. The nomenclature follows that of Rehder's Manual (4) and, when differing from that of Gray's Manual (5), is followed, in parenthesis, by the latter name.

Half of the genus *Vaccinium* occurring in Maine is blueberries and this is the group of greater economic importance. The species are listed in descending order of their economic importance. This order is the same as that presented in 1898 by Munson (2) when consideration is given to combining of species. (*V. nigrum* Wood is here considered as a variety of *V. angustifolium* Ait., and *V. atrococcum* (Gray) Heller is added to Munson's list.) There are no reliable figures on the blueberry area in Maine. Munson (3) states, "In the southeastern part of Maine there are about 150,000 acres known as 'blueberry barrens'". Woods (6) believed there were 250,000 acres and unpublished estimates have placed the area at about 400,000 acres.

Vaccinium angustifolium Ait., commonly called the low-bush blueberry or the low sweet blueberry, is generally distributed over the entire State. The plant is of economic importance, however, only along the coast and of this area the greatest financial returns are from the canning area in the eastern section, Fig. 1.

The typical form of this species occurs only rarely or not at all in the economic areas and where it is found it is thought by growers to be a diseased plant. *Vaccinium angustifolium* var. *laevifolium* House (*V. pennsylvanicum*) is the most important variety and is represented in Fig. 1 by the majority of the stations. *V. angustifolium* var. *nigrum* (Wood) Dole is the next most important variety economically and is marketed with the former for canning. The dark-colored berries produced by the variety *nigrum* are usually considered undesirable for the fresh fruit market. *V. angustifolium* var. *leucocarpum* (Deane) Rehd. is found over the entire State but is so rarely seen that it is considered by most people as a curiosity.

Vaccinium canadense Richards., commonly called sour-top or velvet-leaf blueberry, has the same botanical distribution as the previous species and approximately the same economic distribution, Fig. 1, but this species seldom occupies as large areas as *V. angustifolium*. In the southeastern portion of Maine these two species furnish the major portion of the income for many of the people, the gross income from the crop being estimated at slightly less than $1,000,000 a year. From the reports of a number of growers it would appear that *V. canadense* is less abundant than it was a number of years ago. While we have no

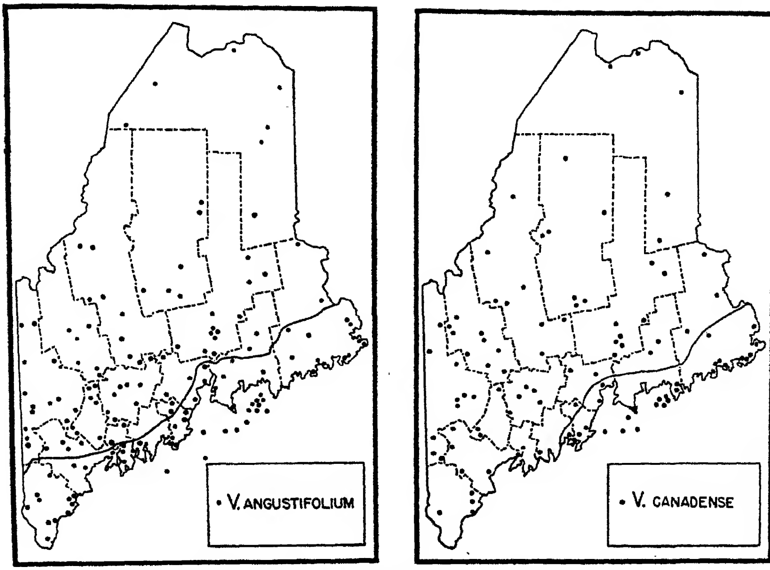

FIG. 1. Stations where *Vaccinium angustifolium* and *V. canadense* have been collected. Stations off the coast represent island collections. Each species is of economic importance in the area between the solid line and the coast.

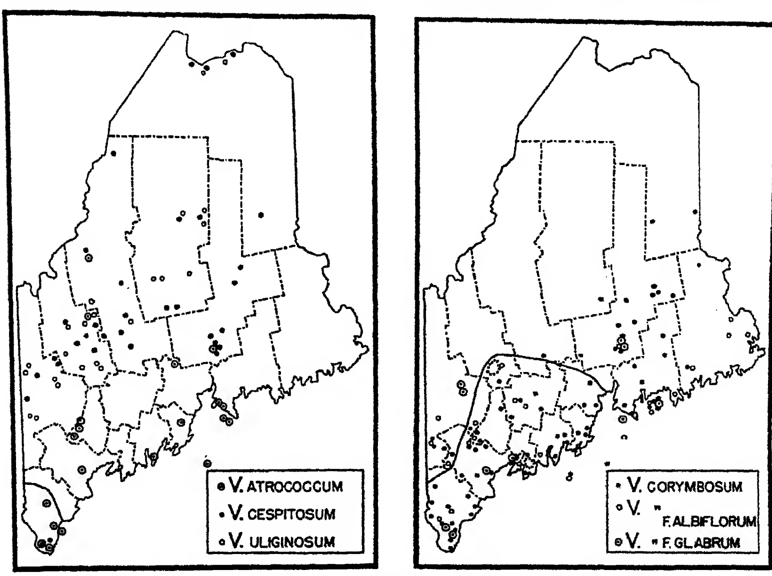

FIG. 2. Stations where *Vaccinium atrococcum, V. cespitosum, V. uliginosum, V. corymbosum, V. c.* forma *albiflorum* and *V. c.* forma *glabrum* have been collected. The economic distribution of *V. atrococcum* and *V. corymbosum* is between the solid line and the coast. The plantings of the named varieties of the latter species are outlined by the dotted lines.

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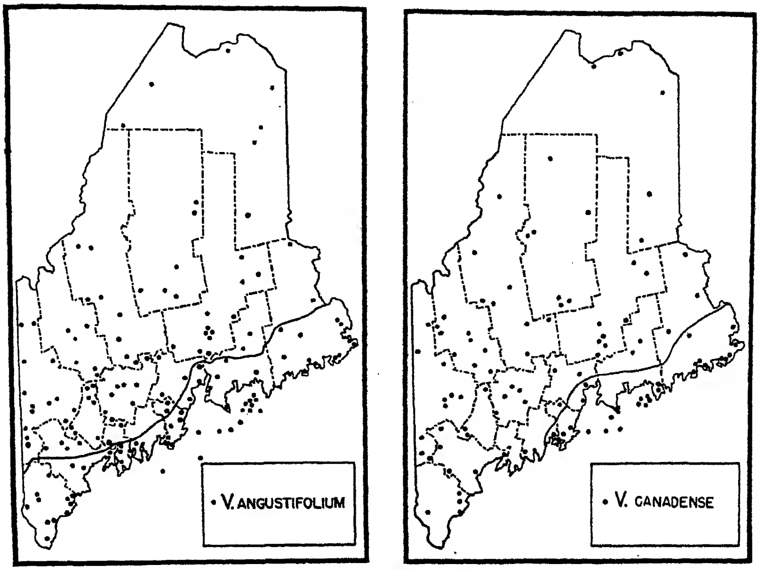

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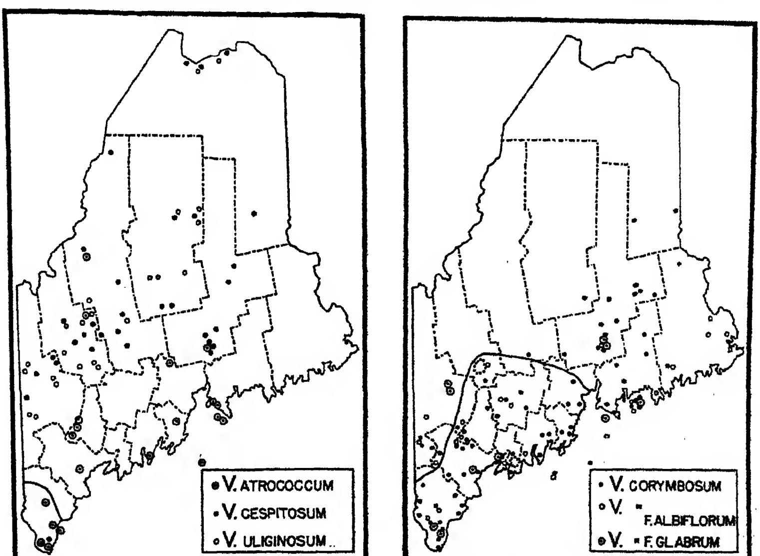

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data at present it appears that *V. canadense* is injured by the pruning (burning) practiced by the growers. Apparently, this same practice increases the spread and fruiting of *V. angustifolium*.

Vaccinium corymbosum L. is fairly well distributed over the southern half of Maine. However, the economic distribution is in small areas, mostly in the southwestern part of the State. The harvest from this species may be divided into two classes — that which is harvested from wild plants, and that harvested from cultivated plantings. There are between 50 and 100 acres of wild plants in the State which are within the area outlined by the solid line in Fig. 2. These areas have received no care in the past and none of the owners has considered a program of renovation. There are slightly over 30 acres of cultivated berries in Maine which are shown in Fig. 2 by the dotted line. The care of the cultivated areas of economic size has been good, but the majority of people who have made small plantings of blueberries for home use have neglected the plants.

Vaccinium atrococcum (Gray) Heller is found in cutover woodlots, swamps, and pastures in the extreme southwestern part of Maine, Fig. 2. This plant is of less importance than *V. corymbosum* yet it enhances the income of a number of families. Because of the black fruit the berries are not shipped out of the State in large quantities.

Vaccinium pallidum Ait. (*V. vacillans*) has nearly the same botanical distribution, Fig. 3, as *V. atrococcum* but the plants are not as numerous and they are usually found in wooded areas where yield is

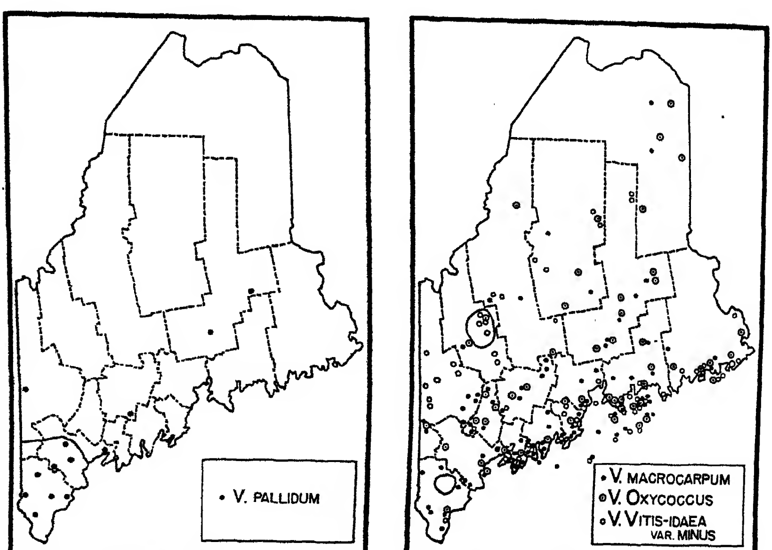

FIG. 3. Stations where *Vaccinium pallidum, V. macrocarpum, V. Oxycoccus* and *V. Vitis-idaea* var. *minus* have been collected. *V. pallidum* is of economic importance south of the solid line. The largest cultivated bogs of *V. macrocarpum* are outlined by solid lines.

small. Plants of *V. pallidum* have not been found with fruit exceeding 13 millimeters in diameter, consequently the fruit of this species is smaller than that of any of the previously mentioned species.

The Bilberry group of this genus is represented by *Vaccinium cespitosum* Michx. and *V. uliginosum* L. The former species does not occur south of latitude 44° 50′ according to Munson (3) but Fernald (1) found an isolated station in York, Maine at 43° 8′. It is occasionally found in the low-bush blueberry fields and is marketed as a blueberry but cannot be considered of any economic importance. *V. uliginosum* L., which is usually considered as a high mountain species, has been reported (3) to be abundant along the ledgy shores of many of the Maine rivers and in the blueberry barrens. This species cannot be considered of any economic importance, Fig. 2.

Cranberries are represented by two species of which *Vaccinium macrocarpum* Ait., the large cranberry, is the more important. This species is found in most of the open bogs, swamps, and along the sluggish streams. The fruit is gathered and marketed locally. There are only a few bogs in Maine where this species is cultivated, and the combined area is probably less than 15 acres. The two locations containing areas of over 3 acres are shown in Fig. 3. *V. Oxycoccus* L. has approximately the same distribution as the former species. This small cranberry is of much less importance but is harvested for local markets.

Vaccinium Vitis-idaea L. var. *minus* Lodd., the mountain cranberry, is found on mountains and hillsides where the soil is shallow, and is abundant near the coast. The fruit is smaller than that of the two preceding species. It cannot be stored like the bog cranberry. The berries of this plant are in demand in the local markets where they bring approximately the same price as those of *V. macrocarpum*.

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Selection of the Low-Bush Blueberry in West Virginia[1]

By W. H. Duis, *West Virginia Agriculture Experiment Station, Morgantown, W. Va.*

ALTHOUGH for many years native low-bush blueberries in West Virginia have annually produced large quantities of fruit, it was not until 3 years ago that any effort was made to improve their horticultural status. At that time the Horticulture Department of West Virginia University, recognizing the extent of the blueberry areas within the state and the wide variation within each of the several species, began a program of plant selection for breeding purposes. Since blueberries will grow on land that is otherwise agriculturally unproductive, and since vast areas of such land are to be found in West Virginia, it was felt that the development of the low-bush blueberry would contribute materially to the improvement of the economic status of the low-income farmer.

For three successive summers during blueberry season, selections of the low-bush species were made in various parts of the state. These selections were made on the basis of the following characteristics: size, flavor, and color of the berry; uniformity of ripening in the cluster; productivity; ease of picking; the presence of a small dry scar where the berry separates from the stem; small calyx; freedom from cracking and tearing; season of ripening; and resistance to insects and diseases. The selection of plants for large-sized berries was facilitated this year by the cooperation of thousands of pickers who annually visit the blueberry areas.

Of the low-bush species in the state, *Vaccinium angustifolium* Ait. and *V. pallidum* Ait. are the most promising for future development. Other species of *Vaccinium* indigenous to West Virginia which may contribute desirable factors to a breeding program include: *V. canadense* Kalm, found in moist areas in the higher Alleghenies, bearing a late-ripening berry of tart flavor; *V. stamineum* L., a prolific plant growing along dry ridges, producing clusters of large, tart berries; *V. erythrocarpum* Michx. growing in damp locations in the higher Alleghenies, blooming late and producing red fruits in September. In addition to these *V. Constablaei* Gray, a species incorporated by Gray under *V. corymbosum* var. *pallidum,* is found in the glades of Nicholas and Webster Counties. These glades, which are approximately 2200 feet above sea level, are poorly drained areas or extensive flood plains lying between surrounding highlands. The soil is largely Dekalb silt loam, smooth phase, a heavy soil with varying amounts of sand and organic matter. The vegetation of the area not under cultivation consists chiefly of *V. Constablaei, Lyonia ligustrina, Corylus americana, Alnus rugosa* and *Acer rubrum.*

In this state *Vaccinium angustifolium* is found chiefly on the Allegheny Plains, vast expanses of comparatively level, rocky land located on the crest of the Allegheny Mountains. These areas, lying in Pendleton, Tucker, Randolph, and Grant counties, and bearing such names

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as Flat Rock Plains, Brushy Ridge, Red Creek Plains, and Roaring Plains, are a part of the Monongahela National Forest. They lie at an altitude of 3000 to 4800 feet above sea level and cover an area of approximately 250 to 300 square miles. At one time these plains were covered with forests of red spruce and hemlock; but with the advent of lumber operations and recurring forest fires, the forests have disappeared and left in their place a cover which consists chiefly of *Gaylussacia baccata, Kalmia latifolia, Rhododendron maximum, Vaccinium angustifolium, V. canadense,* and other ericaceous plants. In addition, *Prunus pennsylvanicum, Sorbus americana, Aronia melanocarpo, Amelanchier spp., Nemopanthus mucronata, Viburnum cassinoides, Alnus incana,* and small *Picea rubra,* constitute for the most part the shrubby growth of this region. *V. angustifolium* forms a carpet or mat of plants covering the well-drained, sandy soil, often as an understory to *Gaylussacia baccata.* It also commonly grows around exposed rocks. The soil type of the plains is classified as rough stony land made up of Dekalb soil materials or as Dekalb stony loam, a dark soil, the upper horizon of which is made up largely of a mixture of grey sand and organic matter. The soil is extremely acid, the pH ranging from 3.6 to 4.3.

Vaccinium angustifolium varies widely in color, size and shape, and flavor of fruit, type of growth, and other characteristics. For example, the intensity of blue which is determined chiefly by the amount of waxy bloom present on the berry, covers a wide range. Light blue, blue, medium blue, and blue-black are to be found within the species; and frequently the entire absence of bloom results in a shining jet black fruit. Some berries are covered with an especially tenacious wax which feels like talc when rubbed with the finger and which is not easily removed by handling. Such berries are particularly desirable for marketing from the standpoint of appearance. Still other plants bear fruit of a metallic blue, referred to by Coville (1) in his work with *V. corymbosum* as "aluminum" and by pickers as "silver berries". Moreover, different degrees of "silverness" occur. The white fruited form, *leucocarpum* Deane, is occasionally found growing among the type form of the species. These berries exposed to full sunlight present a blushed cheek or become entirely red.

Wide variation likewise appears in the size of the berries. Diameters range from 5 millimeters to 15 millimeters. There is an equally wide range in the lengths of the berries, a factor which is not to be neglected in the selection for size. A cup count (the number of berries required to fill a standard measuring cup, a common method of ascertaining the size of blueberries) of a sampling of berries taken from pickers' crates early in the season numbered 548; a similar sampling taken later in the season numbered 348. This increase in size may be attributed to an increase in volume of the fruit as the season progresses, to the possibility that the later-ripening berries on the average are larger, or to a combination of the two factors.

In shape the fruits of *Vaccinium angustifolium* range from globose to spherical to pear-shaped. In flavor they range from flat to sweet to sub-acid to acid.

Leaf spot appears to be the most serious disease affecting *Vaccinium angustifolium* in West Virginia. The fact that some plants are not affected may indicate immunity. It is important, of course, to select if possible plants that are free from leaf spot; however, the disease appears to be controlled by spraying. This fact was recently observed in the Chert Mountain Orchards of E. A. Leatherman, Romney, West Virginia, where *V. angustifolium* and *V. pallidum*, growing as an undercover to apple trees, were entirely free from leaf spot. Since most of the plants in adjacent areas were affected, it was assumed that those growing in the orchard had been protected by the apple-spray schedule.

In order that the season of ripening may be extended over a long period of time, selections were made from early-, medium-, and late-ripening types. *V. angustifolium* ripens over a period of 5 weeks, generally beginning the first week in July. The earliest-ripening form is a low bush, ranging from 6 to 8 inches in height. Its leaves, somewhat erect and elliptical, with bristly serrate margins, are bright green on both surfaces, the under side somewhat lighter than the upper. The petioles and veins are devoid of hairs, although the stems are hairy. This type, called "early sweet" by the pickers, grows abundantly on open sandy ridges. It usually ripens during the first two weeks in July. Those plants which fruit shortly afterwards, the medium-ripening types, bear more or less the same physical characteristics as those just described. The late-ripening types, however, are generally from 10 to 20 inches in height, and the leaves are more horizontal than those of the low "early-sweet". In some of the late-ripening plants the leaves are devoid of hairs, in others both the midrib and secondary veins are hairy and in still others only the midrib is hairy.

Growing among *Vaccinium angustifolium* is *V. angustifolium nigrum* Wood, an extremely prolific plant, likewise appearing in the low, early-ripening and tall, late-ripening forms. Its leaves are blue-green in color; its berries range from jet black to grey. The prolific character of this variety and the fact that its berries are borne in terminal clusters are two qualities which make it a desirable plant for breeding purposes.

Selections of *Vaccinium pallidum* were made on the basis of the characteristics which determined those of *V. angustifolium*. In both species wide variations exist, but a few marked differences may be noted in the characteristics of the two. For example, *V. pallidum* is inferior to *V. angustifolium* in the following respects: the blue color of the berry is less intense; the fruit is not so highly flavored, and the variation in the size of fruit is not so great, that of *V. pallidum* being generally smaller. The cup count of a sampling from pickers' crates numbered 445. On the other hand the fruit of *V. pallidum* is firmer than that of *V. angustifolium* and has a dryer scar, and the fruit cluster is larger. The ripening season of *V. pallidum* covers a period of 2 or 3 weeks usually beginning the latter part of July, although the time of ripening depends upon the altitude. *V. pallidum* is widely distributed throughout the state, growing on well-drained sandy ridges, usually at an altitude below 2,400 feet, and is commonly referred to as the "ridge huckleberry". The pH of the soil in which it commonly grows ranges from 4 to 4.7.

In West Virginia, *Vaccinium angustifolium* and *V. pallidum* show more promise for development as an economic fruit than any of the other *Vaccinium* species indigenous to the state. Advantage has been taken of the wide variations within each of the two species, and selections for various characteristics have been made.

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Effect of Some Nutrients, Media, and Growth Substances on the Growth of the Cabot Blueberry[1]

By AMIHUD KRAMER and A. L. SCHRADER, *University of Maryland* and *Soil Conservation Service, College Park, Md.*

ABSTRACT

This material will be published in full elsewhere as Scientific Contribution No. 530, Department of Horticulture, Maryland Agricultural Experiment Station.

ROOTED cuttings of the Cabot blueberry were grown in peat-sand and sand media, and supplied with various nutrient solutions and growth substances.

Deficiency symptoms appeared after different periods of time in the following order: Nitrogen, potassium, sulphur, calcium, boron, magnesium, phosphorus, iron, and manganese. The beneficial effect of peat was partly due to the presence of calcium, sulphur, and boron in available form, and partly to factors that could not be determined, since plants receiving the full nutrient solution also made better growth, although to a lesser degree, in peat-sand than in sand alone.

The shoot-root ratio of plants growing in the peat-sand medium was greatly increased when manganese, iron, calcium, boron, or magnesium was omitted, and decreased when sulphur, boron, phosphorus, or nitrogen was witheld from the sand grown plants.

There was a significant negative correlation between fresh weight and per cent dry weight, but results based on dry weight were practically identical with those obtained with fresh weights, since the differences in weight were sufficiently large to be maintained on dry weight basis also.

Nutrients had a significant effect on the rapidity with which terminal growing points aborted. There was a significant correlation between per cent of terminals aborted and top weight.

Weekly applications of thiourea and vitamin B_1 had no significant effect on the deficiency symptoms, fresh or dry weights, or growing point abortion. Eight other substances applied to blueberry plants growing in silt loam soil in various concentrations and combinations had no significant effect.

[1]A cooperative study by the Department of Horticulture, University of Maryland, and the Hillculture Division, Soil Conservation Service, United States Department of Agriculture.

Seed Size in Blueberry and Related Species[1]

By George M. Darrow, *U. S. Horticultural Station, Beltsville, Md.*

IN 1931 a study of seed in cane fruits showed the percentage of total berry weight consisting of seed was 4.35 for Cuthbert raspberry, 8.92 for Farmer black raspberry, 3.93 for Lawton, 5.04 for Evergreen, and 3.38 for Young blackberries. In 1939 a similar survey of seed in strawberries showed about 1.30 per cent of the berry weight was seed. Seeds of octoploid strawberries averaged twice the size of the diploid. However, some octoploid varieties had relatively small seeds and among selections there were some that had seeds as small as the diploid. Therefore, if the seed size is doubled when chromosome number is doubled strawberries may still not be "seedy".

In blueberry varieties the Sam (of the northern highbush) and the Ruby (of the rabbiteye) are said to be relatively seedy, though probably not objectionably so. The species of blueberries are of three chromosome groups. Huckleberries are generally assumed to have larger seeds than blueberries. This study of blueberry and related species was planned with these points in mind and to determine whether seed size followed chromosome number.

A test was made of seed weight as a measure of seed size. Weight was found to vary directly as volume and hence was used in this study. Where possible 100 plump seeds of each variety or species were weighed. Several checks of the accuracy of the work were made. Thus 100 fully developed seeds of Mineola weighed .0611 grams and 100 small undeveloped seeds weighed only .0145. In a lot of 700 seeds of Rubel, the large plump seeds averaged .043 per hundred and the small undeveloped seeds averaged only .013 per hundred. Care was therefore taken that all seeds utilized in these studies were fully developed. Two lots of five samples and one lot of 10 samples of 100 seeds each were weighed to check the accuracy of this size sample. The variations from the mean were 7, 6, and 9 per cent. Seeds were collected from northern Florida, northward to Massachusetts. Seeds of most of the cultivated varieties are included in this study.

Table I gives the weight of seeds of species, varieties, and selections. Where the seed used resulted from hand pollinations, the pollen parent is put in parenthesis as (x Dixi). Otherwise the seed resulted from open pollination.

The data in the table show that, in general, the diploid and tetraploid species and varieties of blueberries have much smaller seeds than do the hexaploid species and varieties. *Vaccinium parvifolium* Smith and *V. crassifolium* Ait (a few seeds only examined) seem to have the smallest seed. *V. atrococcum* (A. Gray) Heller varies in size of seeds from that nearly as small as the above to that of seed about twice the size. *V. angustifolium* Ait. had smaller seed than *V. corymbosum* L. and nearly as small as that of *V. crassifolium* and *V. parvifolium*.

[1]Acknowledgment of the help of R. D. Rappleye, Student Aid, in obtaining the data for this article is gratefully given.

TABLE I—SEED SIZE BY WEIGHT OF BLUEBERRY VARIETIES, SPECIES AND RELATED PLANTS (WEIGHT OF 100 SEEDS IN MGS)

Material	Source and Weight (Mgs)	
CRANBERRY		
Vaccinium macrocarpum Ait. *Varieties*		
Aviator	Mass.	77
Black Veil	Mass.	84
Centennial	Mass.	101
Early Black	Mass.	93
Howes	Mass.	106
Smalley Howes	Mass.	91
Vose Pride	Mass.	89
DEERBERRY		
Polycodium stamineum (L.) Greene	Md.	63
HUCKLEBERRY		
Gaylussacia baccata (Waugh.) K. Koch	Md.	136
brachycera (Michx.) A. Gray	N. J.	106
frondosa (L.) Torr. & Gray	Md.	167
frondosa (L.) Torr. & Gray	N. C.	161
Batodendron arboreum Marsh.	Fla.	97
BLUEBERRIES		
Vaccinium parvifolium Smith	Ore.	21
uliginosum (L.)	Ore.	29
Diploid Species		
Vaccinium atrococcum (A. Gray) Heller	Md.	43
atrococcum (A. Gray) Heller	Md.	32
atrococcum (A. Gray) Heller	Md.	36
atrococcum (A. Gray) Heller	Md.	30
atrococcum (A. Gray) Heller	Md.	21
Elliottii Chapm.	Ga.	41
Elliottii Chapm.	Fla.	35
tenellum Ait.	N. C.	26
vacillans Torr.*	Ala.	41
vacillans Torr.	Ga.	35
vacillans Torr.	Md.	26
canadense Richards × *V. vacillans*	N. J.	37
vacillans (×*V. atrococcum*)	Md.	35
ovatum Pursh (×*V. atrococcum*)	Md.	20
ovatum 11 collections	Ore.	33 to 44
Tetraploid Species		
Vaccinium angustifolium Ait.†	W. Va.	25
	N. J.	22
	W. Va.	21
angustifolium var. *nigrum* (Wood) Dole	W. Va.	27
angustifolium var. *nigrum* (Wood) Dole	W. Va.	32
angustifolium var. *nigrum* (Wood) Dole	W. Va.	34
corymbosum L.	Md.	46
corymbosum L.	Md.	47
tallapusae (Cov.) Uphof (×Dixi)	Md.	34
(×Stanley)	Md.	44
(×Stanley)	Md.	31
Myrsinites Lam. (×Weymouth)	Md.	39
corymbosum L. (×*virgatum* Ait.)	Md.	66
corymbosum L. seed:		
Dixi (×*V. angustifolium*)	Md.	63
(×AH 78)	Md.	64
(×*V. tallapusae*)	Md.	72
(×*V. Myrsinites*)	Md.	53
(×*V. virgatum*)	Md.	78
Stanley (×*V. virgatum*)	Md.	59
Weymouth (×*V. angustifolium*)	Md.	38
(×*V. angustifolium*)	Md.	44
(×*V. Myrsinites*)	Md.	63
(×*V. virgatum*)	Md.	67
AH 78 (×Dixi)	Md.	34
(× Weymouth)	Md.	31
V. angustifolium (×Dixi)	Md.	45
Vaccinium corymbosum L. *Varieties*		
Adams	N. J.	45
Atlantic	N. J.	43
Brooks	N. J.	39
Burlington	N. J.	39
Cabot	N. J.	39
Chatworth	N. J.	44
Dixi	Md.	52
Dunfee	N. J.	42
Grover	N. J.	42
Jersey	N. J.	42
Jersey	N. J.	45
June	N. C.	43
Katherine	N. J.	47
Pemberton	N. J.	52
Pemberton	N. J.	53
Pioneer	N. J.	43
Rubel	N. J.	34
Sam	N. J.	57
Scammell	N. C.	50
Sooy	N. J.	53
Stanley	N. J.	46
Weymouth	Md.	40
A. W. 35	Md.	43
G. M. 37	N. J.	41
V-20	N. J.	54
V-25	N. J.	61
1613-A	N. J.	37
Vaccinium corymbosum × *V. angustifolium Varieties*		
Catawba	N. J.	41
Catawba	N. J.	38
Greenfield	N. J.	39
Redskin	N. J.	30
Redskin	N. J.	24
Hexaploid Species		
Vaccinium pallidum Ait.	N. C.	50
(*Vaccinium pallidum* × *V. virgatum*) selfed	Md.	51
Vaccinium virgatum	N. C.	55
Vaccinium virgatum Varieties		
Black Giant	Ga.	69
Black Giant	Ga.	66
Blue Boy	Fla.	65
Clara	Ga.	53
Clara	Ga.	54
Hagood	Ga.	62
Hagood	Ga.	54
Locke	Fla.	71
Myers	Ga.	59
Myers	Ga.	64
Myers	Ga.	47
Mineola	Ga.	61
Mineola	Ga.	52
Ruby	Ga.	83
Ruby	Ga.	92
Suwanee	Ga.	48
Suwanee	Ga.	59
Vaccinium virgatum Seed		
Black Giant (×Clara)	Md.	66
(×Hagood)	Md.	78
(×Long)	Md.	63
(×Pecan)	Md.	80
Hagood (×Black Giant)	Md.	74
(×Clara)	Md.	73
(×Long)	Md.	69
Myers (×Black Giant)	Md.	68
(×Clara)	Md.	58
(×Hagood)	Md.	69
(×Long)	Md.	59
(×Ruby)	Md.	72
Suwanee (×Black Giant)	Md.	72
(×Hagood)	Md.	61
(×self)	Md.	77
(×Dixi)	Md.	42
(×Stanley)	Md.	38
(×Weymouth)	Md.	44

*? tetraploid. †? diploid.

Seeds of Sam, Dixi, Pemberton, V-20 and V-25 are relatively large but the berries of all these except Sam are also very large. All the varieties of the hexaploid species, *V. virgatum* Ait., have relatively large seeds. Ruby has the largest seed of any blueberry. Possibly in this species the seeds are so large that seed size should be considered in making selections of seedlings in breeding work. Seed of the huckleberries is from three to four times as large as that of the blueberries. Seed of the deerberry (*Polycodium stamineum* (L.) Greene) is about the size of the hexaploid blueberries although the deerberry is reported to be diploid.

It is rather notable that hybrid seed of Dixi is larger in most instances than is the open-pollinated seed of Dixi.

Although open-pollinated seed of varieties of the "rabbiteye" are large, and when one rabbiteye variety is pollinated with another the seeds are also large; in contrast, the seeds resulting from pollinating Suwanee by Dixi, Stanley, and Weymouth are smaller—about the size of the tetraploid pollen parent. However, hybrid seed resulting from pollination of Weymouth and of Stanley with *Vaccinium virgatum* is larger than open-pollinated seeds of the same varieties.

The number of seeds in relation to the size of berry was obtained for open-pollinated GM-37, a selection of *Vaccinium corymbosum*. Very large berries averaging 55 to the blueberry cup (½ pint) had 33.1 ± 8.4 plump seed, large berries averaging 75 per cup had 18.3 ± 6.3 seed, medium sized berries averaging 110 per cup had 11.0 ± 5.0 seed, and small berries averaging 256 per cup had 2.1 ± 1.5 seed per berry. Counts of the number of seeds per berry gave an average of 17 seeds for *Polycodium stamineum* (range 5 to 29) and 70 for the Rubel blueberry. In per cent of the total berry weight the huckleberry (*Gaylusaccia frondosa*) (L.) Torr. & Gray had 4.8 per cent of seeds, Rubel 1.1 per cent, and the deerberry (*Polycodium stamineum*) 0.9 per cent. Because the huckleberry is considered to be objectionably seedy and the Rubel blueberry is not, the ratio of seed weight to total weight of berry that is objectionable may be presumed to be between these two figures. However, as in Rubus the degree of attachment and character of the fibers may largely determine the impression of seediness in eating.

Leaf Characters as a Basis for the Classification of Blueberry Varieties[1]

By J. HAROLD CLARK, *New Jersey Agricultural Experiment Station, New Brunswick, N. J.*

THE list of named varieties of the high-bush blueberry, *Vaccinium corymbosum* and hybrids, has grown to a point where some method of classification would be helpful. Coville (2) has described certain blueberry varieties as having entire leaves and others as having serrate leaves. He also stated that there are leaf size differences and shape differences, but did not attempt to group the varieties. The value of leaf characters in the classification of varieties of other fruits has been shown by numerous writers. Recently Sefick and Blake (6) and Meader and Blake (3), have shown the practicability of using actual measurements of leaf tip angles, base angles, and width-length ratios in classifying varieties of peaches. Bioletti (1) and Rodigues (5) have shown that certain angles of the grape leaf have taxonomic value.

LEAF GAUGE DEVELOPED

In a preliminary study of blueberry leaves during the summer of 1940, it became evident that a rapid method of measuring the various leaf angles and dimensions would be helpful. Accordingly the device shown in Fig. 1, known as the New Jersey Blueberry Leaf Gauge, was developed to permit the securing of most of the important leaf measurements with a minimum of motion.

The vertical scale, 10 centimeters long, is for leaf blade length. The 5 centimeters scale is for leaf width, the lines being rather long, so that the point of maximum width may be quickly located.

The horizontal scale at the top is for direct measurement of the tip angle. The tip of the leaf should be placed so that it just touches the top line with the mid-rib extending straight down, parallel to the vertical line at the left. The leaf should be moved to right or left until the left margin crosses the vertical line at its point of intersection with the horizontal line, which is 0.5 inch below the top line. At the point where the right hand margin of the leaf crosses this lower line, the angle of the tip, at a vertical distance of 0.5 inch from the end of the leaf may be read off in degrees. This method of measuring tip and base angles, by a scale based on natural tangent values, was worked out by Mr. E. M. Meader (4) who has been using it in peach variety studies.

The horizontal scale at the bottom is used to measure the base angle, the base of the blade being placed on the bottom line, the left margin on the intersection of the vertical and the 0.5 inch horizontal line, and the angle read off directly on the scale, at the point where the right hand margin intersects the 0.5 inch line. The exact point at the base of the blade to be placed on the bottom line is where the margin lines of the blade would cross if projected across the petiole.

The small scale, measuring to 110 degrees is for leaves so small that

[1]Journal Series Paper of the New Jersey Agricultural Experiment Station, Department of Pomology.

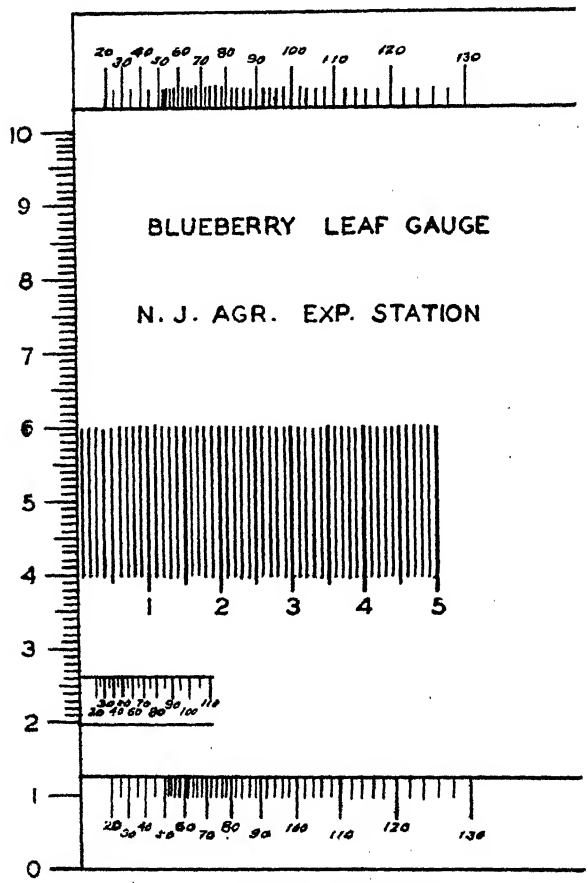

FIG. 1. Blueberry leaf gauge.

the angles may be measured more accurately at a distance of 0.25 inch than at 0.5 inch from the ends of the leaf blade. The larger scales should be more satisfactory for most varieties of *Vaccinium corymbosum* and were used exclusively in these studies.

SELECTION OF CRITERION LEAVES

A standard method of selecting the criterion leaves is most important in a study of this kind. There is great variation in size, and some variation in shape of leaves on blueberry twigs or shoots of different sizes and degrees of vigor, hence average size or average shape for the variety, if based on all the leaves of a plant, would be difficult to determine. Furthermore, such an average would be of no greater value than an average based on leaves from one particular place on one type of twig. Leaf bearing wood on a mature blueberry plant may be of two types (a) primary canes from the crown of the plant or from

near the base of older growth, and (b) lateral branches on older growth. However, old plants may have no typical primary shoots, either because of poor growing conditions or insufficient pruning. In these studies, therefore, leaves were selected from lateral branches 8 to 12 inches long, on vigorous plants of bearing age. Branches making second growth were not used.

On any lateral branch, the leaves range from very small at the base to a maximum size near the tip. The leaf shape also varies somewhat from the base to the tip of the twig. To determine the average size and shape of leaf on a twig of this type would require a great many measurements. The largest leaves, one to three from a twig, taken from near the tip are the easiest to select and describe accurately and so were chosen as criterion leaves. These larger leaves would be the ones most likely to be noticed and retained in the memory of the average observer as typical of the variety. Whether they are more or less variable than the leaves on other parts of the twig will require more extensive statistical studies to determine.

Leaves Shrink Very Slightly on Being Dried

In order to determine the best method of handling the material, leaves of six standard varieties were collected on September 12, 1940 and measured immediately, after which they were pressed, thoroughly dried, and measured again. Table I shows the average loss in size for each dimension. It is evident from the table that the shrinkage due to drying was comparatively small. All other measurements have been made on dry leaves.

During September and October 1940, leaves were collected from the Horticultural Farm at New Brunswick and from commercial fields in various parts of the state. Time did not permit the collection of samples of each variety from plants growing under different environmental conditions. Rubel leaves, however, were collected on several farms and the measurements are shown in Table II.

There is considerable variation in the different lots recorded in Table II yet only two other varieties of the 28 measured had mean apex angles falling between the two extremes here recorded for Rubel, 63.6 and 68.9 degrees. There was greater variation in the base angles, however, and 10 other varieties of the 28 fell within the extremes of 68.4 and 77.7 degrees. The coefficient of variation for the apex angles of the 50 leaf sample was 5.46 per cent and for the base angles 6.71 per cent. Eight other varieties had a width to length ratio within the

TABLE I—Average Change in Leaf Dimensions Due to Drying, Based on 10 Leaves of Each Variety

Variety	Apex Angle (Degrees)	Base Angle (Degrees)	Blade Length (Cms)	Blade Width (Cms)	Width Length Ratio
Adams	−0.1	−1.0	−0.10	−0.09	−0.01
Cabot	−0.6	−0.8	−0.13	−0.08	0.00
Concord	−0.2	−1.1	−0.10	−0.06	0.00
Grover	−0.4	−0.6	−0.07	−0.08	0.00
Rancocas	−0.7	−0.7	−0.07	−0.05	0.00
Rubel	−0.6	−1.0	−0.06	−0.06	−0.01

TABLE II—AVERAGE MEASUREMENTS OF RUBEL LEAVES FROM DIFFERENT FARMS

Farm	Soil	No. of Leaves	Vigor of Plants	Apex Angle	Base Angle	Blade Length	Blade Width	Width Length Ratio
1	Upland loam	50	Vigorous	68.9	76.7	5.48	2.63	0.48
2	Loamy sand	10	Vigorous	66.1	77.7	6.05	2.80	0.46
3	Loamy sand	10	Vigorous	64.6	71.9	6.25	2.69	0.43
3	Loamy sand	10	Medium Vigorous	63.6	69.8	5.72	2.45	0.43
4	Loamy sand	10	Medium Vigorous	66.8	68.4	5.29	2.32	0.44
4	Sand	10	Weak	65.1	72.3	5.66	2.53	0.45

range .43 to .48. The range of soil types and degrees of vigor covered in Table II are intentionally extreme and yet the various measurements are consistent enough to be of value for classification purposes.

The actual figures for the other varieties are not presented at this time, as they are based on small samples, usually 10 carefully selected criterion leaves, and one year's observations. Some of the most important varieties, at least, should be studied further under different soil and climatic conditions. The results already obtained, however, seem to warrant a tentative grouping of varieties into the following classes. Apex angle narrow—less than 70 degrees; medium—70 to 80 degrees; wide—over 80 degrees. Base angle narrow—less than 80 degrees; medium 80 to 90 degrees; wide—over 90 degrees. Width to length ratio small—less than 0.45; medium—0.45 to 0.55; large—over 0.55.

There are many other leaf characters which may be of value in the identification of a variety. Some of them, such as size, color and autumn coloration, may be affected to a considerable extent by growing conditions. The erectness of the leaves, the folding and reflexion of the blades, and the waving of the margins are valuable characters, but these also may be affected by environment. Two of the most constant characters are the presence or absence of serrations on the margin of the leaf and presence or absence of pubescence on the under-surface of the leaf. Accordingly, these two characters are used to designate the first sub-divisions in the preliminary classification which follows.

PRELIMINARY CLASSIFICATION OF BLUEBERRY VARIETIES BASED ON LEAF CHARACTERS

- A. Margin entire
  - B. Glabrous lower surface
    - C. Apex angle narrow
      - D. Base angle narrow
        - E. Width/length small—Dunfee
        - EE. Width/length medium—Cabot, Rubel, Scammell, Weymouth
      - DD. Base angle wide—Adams
    - CC. Apex angle medium
      - D. Base angle narrow—Concord
      - DD. Base angle medium
        - E. Width/length medium—Dixi, Sam
        - EE. Width/length large—June, Sooy

DDD. Base angle wide—Atlantic, Brooks
CCC. Apex angle wide
D. Base angle medium
E. Width/length medium—Burlington
EE. Width/length large—Jersey
DD. Base angle wide—Katherine, Pemberton, Pioneer, Stanley
BB. Pubescent lower surface—Grover
AA. Margin serrate
B. Glabrous lower surface
C. Apex angle medium
D. Base angle narrow—Catawba, Greenfield
DD. Base angle medium—Rancocas
BB. Pubescent lower surface
C. Apex angle narrow—Harding, Redskin, Wareham
CC. Apex angle medium—Chatsworth

This classification does not differentiate every variety from every other variety but does put them in relatively small groups. Most of these small groups may be readily subdivided by the following supplementary information, as well as by flower, fruit, and other characters.

Dunfee has leaves that are distinctly variegated. Scammell and Cabot leaves are small, 5 centimeters or less, whereas Rubel and Weymouth have larger leaves, 6 centimeters or more for criterion leaves on vigorous bushes. The Cabot bush is low and spreading, Scammell upright spreading. The Rubel bush is distinctly upright with most of the leaves quite erect. Old plants of Weymouth have not been observed but it apparently does not grow nearly so erect as Rubel.

Dixi has not been observed extensively but does not make as sparse and willowy a growth as Sam.

June leaves are much smaller than those of Sooy, slightly over 5 centimeters long, as compared with 7 centimeters for Sooy.

Brooks and Atlantic may be difficult to distinguish by leaf characters but Atlantic probably has a somewhat thinner leaf blade which is more reflexed and more puckered and waved than Brooks. The difference is slight, however.

Burlington and Jersey fall in different classes on the basis of the measurements made but the difference is not great; these two varieties need additional study.

Stanley has the widest base angles of any variety studied averaging 101 degrees and the leaves are distinctly puckered. Pemberton has a very vigorous, upright bush, whereas Pioneer is low and spreading and Katherine only slightly more upright than Pioneer. The Katherine leaves tend to be slightly more puckered than those of Pioneer.

Catawba is red fruited, whereas Greenfield is blue black.

Redskin has small leaves, just over 4 centimeters long, whereas Harding and Wareham have large leaves, over 7 centimeters long. Harding and Wareham are difficult to distinguish by the leaves but Wareham leaves are slightly more erect than those of Harding.

Summary

A gauge for the rapid measurement of blueberry leaves is described. Blueberry leaves shrink so slightly while being pressed and dried that measurements of either green or dry leaves would be satisfactory for classification purposes. Leaf measurements of the Rubel variety from plants growing under different environmental conditions varied somewhat but were close enough to be of value in classifying the variety. A tentative classification of varieties based on leaf characters is presented.

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Yield, Size of Berries, and Season of Maturity of the Highbush Blueberry as Influenced by Severity of Pruning

By W. T. Brightwell, *Clemson Agricultural College, Clemson, S. C.*

BECAUSE little data are available which give yield records of pruned and unpruned plants, this experiment was planned to obtain further data on the effects of pruning the highbush blueberry (*Vaccinium corymbosum*). The experiment was begun during the season of 1939 at the South Haven Experiment Station plantation near South Haven, Michigan. This paper is a preliminary report of the first two seasons' work. The experiment will probably be continued several years as definite conclusions should not be reached after only two years results.

Materials and Methods

Plants of the Rubel and Pioneer varieties which had been set in the field in 1929 were selected. The plants were set 4 feet by 9 feet on a fairly uniform Saugatuck sandy loam. These plants had received a moderate pruning and clean cultivation until harvest time each season and an application of a specially prepared 5–8–10 fertilizer since the second season.

To facilitate a clearer understanding of the terms used in this paper to designate the different parts of the plant, the following terms are defined: *Shoot* refers to new growth originating at or near the base of the plant the previous season. *Stem* designates shoot growth more than 1 year old. *Lateral* refers to fruiting wood of the past season's growth, other than shoot growth.

Plots containing 10 plants each were pruned in 1939 and 1940 in a similar manner. One plot of each variety received the following treatments: Check plots received no pruning; light method consisted of removing most of the bushy thin wood and light heading back of shoots; intermediate method consisted of removing the bushy thin wood, about one-third of the oldest stems, and a moderate heading back of shoots; heavy method consisted of removing the bushy thin wood and at least one-third of the oldest stems, heading back all shoots, and reducing the number of fruit buds about 60 per cent by heading back each lateral; moderately heavy method was similar to the heavy method except the number of fruit buds was not reduced by heading back each lateral.

The berries were picked and weighed at intervals of varying length as they reached maturity. Comparative size was determined by counting the berries required to fill a ½ pint liquid measuring cup. The sizes were compared to the Michigan Blueberry Growers' Association grades which are: Superior, 90 berries or less; Golden Moon, 91 to 140 berries per cup; Columbia, 141 to 190 berries per cup; and Lake State, over 190 berries per cup.

Discussion of Results

The data, presented in Table I, show that the total yield of berries from plants of the Rubel variety decreased as severity of pruning increased, except in the 1940 season when the moderately heavy pruned plants yielded less than did the heavily pruned plants. The average yield per plant in the 1939 season decreased from 376.6 ounces for the check plot to 62.4 ounces for the heavily pruned plot, a difference of 314.2 ounces. The difference in average yield per plant in 1940 in the same plots was 175.9 ounces. The average yield increased in all pruned plots the second season over the first, but the yield of the check plants decreased.

Table I also shows that the average size of berries increased as severity of pruning increased in the 1939 season but the berries from the check plants were larger in the 1940 season than those from plots pruned by either the light or intermediate method. An abundant moisture supply during the growing seasons was probably largely responsible for the relatively large size and yield of berries from the lightly pruned and check plots. During June 1939 the rainfall was 5.39 inches,

TABLE I—Effects of Pruning Methods on Average Yield of Plants, Size of Berries and Season of Maturity of the Rubel Variety (Average of Ten Plants)

Treatment	Date of Picking		Ave. Wt. Berries Per Plant (Ozs)		Total Yield (Per Cent)		Ave. No. Berries Per Grading Cup	
	1939	1940	1939	1940	1939	1940	1939	1940
Check, no pruning	Jul 28–30	Aug 1–3	122.9	68.5	32.6	21.3	157	131
	Aug 9	Aug 8–10	132.5	96.2	35.2	30.0	209	163
	Aug 18–21	Aug 15–20	80.3	91.9	21.3	28.6	215	202
	Aug 28	Aug 28–30	31.6	51.2	8.4	15.9	256	195
	Sep 4	Sep 5	9.3	11.4	2.5	3.6	274	216
		Sep 13		2.0		.6		
		Total	376.6	321.2		Ave.	222	181
Light method	Jul 28–30	Aug 1–3	172.9	63.5	62.5	20.0	141	143
	Aug 9	Aug 8–10	76.2	111.5	27.4	35.0	176	183
	Aug 18–21	Aug 15–20	23.8	87.4	8.6	27.4	201	224
	Aug 28	Aug 28–30	5.1	42.8	1.8	13.4	243	220
	Sep 4	Sep 5	1.6	10.7	.5	3.3	301	251*
		Sep 13		2.9		.9		
		Total	276.6	318.8		Ave.	189	204
Intermediate method	Jul 28–30	Aug 1–3	152.2	61.7	64.1	24.8	129	135
	Aug 9	Aug 8–10	61.8	89.3	26.0	35.9	174	167
	Aug 18–21	Aug 15–20	17.7	65.8	7.5	26.4	185	192
	Aug 28	Aug 28–30	4.6	23.7	1.9	9.5	230	225
	Sep 4	Sep 5	1.2	7.2	.5	2.9	228	241*
		Sep 13		1.3		.5		
		Total	237.5	249.0		Ave.	174	192
Moderately heavy method	Jul 28–30	Aug 1–3	101.0	39.6	83.1	30.8	118	131
	Aug 9	Aug 8–10	18.4	54.2	15.1	42.2	156	160
	Aug 18–21	Aug 15–20	1.7	26.5	1.4	20.6	219	217
	Aug 28	Aug 28–30	.3	7.1	.3	5.5		
	Sep 4	Sep 5	.1	.8	.1	.6		
		Sep 13		.3		.2		
		Total	121.5	128.5		Ave.	164	169
Heavy method (Nine plants averaged)	Jul 28–30	Aug 1–3	58.3	51.5	93.4	35.4	100*	108*
	Aug 9	Aug 8–10	3.4	62.7	5.3	43.3	145*	136*
	Aug 18–21	Aug 15–20	.4	26.2	.6	18.0	190*	159*
	Aug 28	Aug 28–30	.2	3.9	.3	2.7		178*
	Sep 4	Sep 5	.1	.7	.2	.5		
		Sep 13		.3		.2		
		Total	62.4	145.3		Ave.	145	145

*Less than 10 cups averaged.

1.94 inches in July, and 2.95 inches in August. The rainfall in June 1940 was 3.81 inches, 1.34 inches in July and 7.86 inches in August. The large number of leaves on the lightly pruned and check plants with abundant moisture enabled the plants to mature a large crop as well as produce moderately vigorous new growth well supplied with fruit buds for the next year's crop. In most cases, the average size of the berries was larger in the late pickings in August in the 1940 season which may be attributed to the large supply of moisture. The average size of the berries probably would have been greatly reduced by a slight drought.

Plants which received the most severe pruning matured a larger percentage of their total crop earlier in the season than those receiving less severe pruning. The first season 98.7 per cent of the total crop of plants pruned by the heavy method were harvested the first two pickings as compared to 67.8 per cent from the check plants. This was not so marked the second season when the range was 78.7 to 51.3 per cent.

The data presented in Table II, show that the average yield of plants of the Pioneer variety decreased as severity of pruning increased. The average yield per plant in the check plot was 404.6 ounces compared to a yield of 93.4 ounces per plant in the heavily pruned plants, a difference of 311.2 ounces.

TABLE II—EFFECTS OF PRUNING METHODS ON AVERAGE YIELD OF PLANTS, SIZE OF BERRIES AND SEASON OF MATURITY OF THE PIONEER VARIETY (AVERAGE OF TEN PLANTS)

Treatment	Date of Picking		Ave. Wt. Berries Per Plant (Ozs)		Total Yield (Per Cent)		Ave. No. Berries Per Grading Cup	
	1939	1940	1939	1940	1939	1940	1939	1940
Check, no pruning	Jul 10–11	Jul 23–24	15.5	31.2	3.8	9.4	122	121
	Jul 19–21	Jul 30–31	51.3	59.5	12.7	18.0	144	103
	Jul 24–25	Aug 6–8	91.9	74.8	22.7	22.6	160	114
	Aug 7–9	Aug 12–14	121.5	96.6	30.0	29.2	178	141
	Aug 15	Aug 21	70.0	37.5	17.3	11.3	217	156
	Aug 28	Aug 30	44.5	30.7	11.0	9.3	228	161
	Sep 4		10.9		2.7		283	
		Total	404.6	330.5		Ave.	190	132
Light method	Jul 10–11	Jul 23–24	13.4	38.2	4.6	12.7	113	121
	Jul 19–21	Jul 30–31	50.7	55.7	17.2	18.5	126	105
	Jul 24–25	Aug 6–8	93.5	75.0	31.8	24.9	134	123
	Aug 7–9	Aug 12–14	81.1	78.5	27.6	26.1	156	140
	Aug 15	Aug 21	37.9	25.4	12.9	8.4	170	164
	Aug 28	Aug 30	14.9	28.2	5.1	9.4	244	165
	Sep 4		2.6		.9		270	
		Total	294.1	301.0		Ave.	173	136
Intermediate method	Jul 10–11	Jul 23–24	13.5	46.1	4.8	26.2	116	113
	Jul 19–21	Jul 30–31	60.9	41.2	21.8	23.4	122	105
	Jul 24–25	Aug 6–8	109.9	52.5	39.4	29.8	128	119
	Aug 7–9	Aug 12–14	66.0	29.7	23.7	16.9	146	138
	Aug 15	Aug 21	23.4	4.1	8.4	2.3	174	174
	Aug 28	Aug 30	5.0	2.6	1.8	1.5	228	
	Sep 4		.3		.1			
		Total	279.0	176.1		Ave.	151	130
Heavy method	Jul 10–11	Jul 23–24	5.7	45.0	6.1	26.0	82	87
	Jul 19–21	Jul 30–31	46.0	45.5	49.2	26.3	82	87
	Jul 24–25	Aug 6–8	33.8	59.4	36.2	34.3	84	96
	Aug 7–9	Aug 12–14	7.4	21.0	7.2	12.1	94	115
	Aug 15	Aug 21	.4	1.8	.4	1.0		
	Aug 28	Aug 30	.1	.3	.1	.2		
	Sep 4							
		Total	93.4	173.0		Ave.	85	99

The average size of the berries increased with severity of pruning in all cases in the 1939 season, but in the 1940 season the berries from the check plot were slightly larger than those from the lightly pruned plots.

Much of the weaker wood was removed the first season (1939) from the plots which were pruned. With this removal of weak wood and weak fruit buds, the crop was reduced and stronger and more vigorous wood developed on which to produce the 1940 crop. The second season (1940) the plants from which most of the weak wood had been removed received a less severe pruning than in 1939 as most of the new growth was vigorous. The better wood and lighter pruning resulted in a heavier yield. The increase in total yield was generally accompanied by a decrease in average size of berry.

A large number of laterals was calipered and yield records taken. The large laterals matured their fruit earlier than did the small laterals. This may explain why the heavily pruned plants which had large laterals matured much of their crop early in the season.

Dates for Applying Blueberry Fertilizer[1]

By CHARLES A. DOEHLERT, *New Jersey Cranberry and Blueberry Research Laboratory, Pemberton, N. J.*

THE object of this experiment was to find, under field conditions, the period during which the application of fertilizer is most effective. The effect of applications at five different periods has been observed for 6 years, beginning in 1935.

The land used in New Jersey for commercial blueberry culture is chiefly St. John's sand. On plowing the virgin soil, the surface layer of acid muck is mixed with the underlying sand. The result is a soil that has a pH ranging from 5.0 to 3.8 and an organic matter content of 2 to 12 per cent. A hardpan is usually found at a level of 8 to 40 inches below the surface.

The blueberry crop can usually be doubled by the proper use of a complete fertilizer if good drainage and pruning have been provided. This point is illustrated by data presented later in this paper.

It was customary practice prior to this experiment for growers to commence fertilizing about May 15, which is a week after the plants are in abundant bloom. The early varieties of blueberries have generally opened 10 per cent of their flower buds during the first week in May. A second application of fertilizer was made generally 2 or 3 weeks later. A few growers waited until some time in June to fertilize. Harvest usually commences June 20 for the main early variety (Cabot) and July 7 for the variety used in this experiment (Rubel).

PLAN OF EXPERIMENT

A row of 70 Rubel plants in the Bluebog field of Joseph J. White Inc. was used. Rubel is a strong-growing, productive variety and is well suited to this locality. The plants were 6 years old and bore at the rate of 97 bushels per acre (all plots) in the first year of the experiment, evidence of good blueberry land well managed. The rows are planted alternately with Rubel and Pioneer for the purpose of cross pollination. This made it impossible to have two or three shorter rows of one variety adjacent to one another.

Ten-inch boards 3½ feet long were set on edge in the soil to separate each plant from its neighbors. These boards extended through the topsoil (to which the blueberry roots confine themselves) and into the clear sand subsoil for a distance of about 2 inches, forming an effective root barrier.

A few plants on each end of the row were discarded because of soil variation, and the remaining 60 plants were divided into groups of 6 each. Within each group the six experimental treatments used were located at random, providing 10 replications.

Fertilizer was used at the rate of 600 pounds per acre (7 ounces per bush) and was made up as follows: 450 pounds calcium nitrate; 450 pounds nitrate of soda; 800 pounds rock phosphate; and 300 pounds sulfate of potash. This treatment was the recommendation of

[1]Journal Series Paper of the New Jersey Agricultural Experiment Station, Cranberry and Blueberry Research Laboratory.

this Station to the blueberry industry in 1937 and has been found satisfactory over a wide range of conditions. It contains 7 per cent nitrogen, 12 per cent phosphoric acid, and 7 per cent K_2O.

One of the treatments is "no fertilizer" to demonstrate the proportionate magnitude of the differences between the fertilizer treatments as compared with the gain over no fertilizer at all. The treatments were as follows:

April 1 and April 15, 300 pounds per acre each date.
April 15 and May 1, 300 pounds per acre each date.
May 1 and May 15, 300 pounds per acre each date.
June 1 and June 15, 300 pounds per acre each date.
May 1, May 15, and October 15, 200 pounds per acre each date.
No fertilizer.

The divided application with a short interval was used to afford protection against burning and, at the same time, concentrate the effect of the fertilizer into a short period.

The fertilizer was broadcast over the area occupied by the roots of the bushes which is roughly a square 4 feet on each side. After broadcasting, the fertilizer was worked into the soil to a depth of about 1½ inches by means of an ordinary iron garden rake. Deeper stirring than this is impractical because of the dense mat of roots the blueberry plant forms in the upper layer of the soil. At each fertilization, the whole row was raked so that the tillage effect might be kept uniform.

Results

Weather had two very large general effects. In 1936, frost on May 15 and extremely hot weather July 9 to 12, reduced the crop to about half of normal. In 1938, abundant moisture and temperatures consistently somewhat above normal were responsible for a crop of twice the normal size.

The average for the 50 fertilized plots combined was, in bushels per acre: 98 in 1935; 43 in 1936; 113 in 1937; 199 in 1938; 97 in 1939; and 107 in 1940.

A summary of results is presented in Fig. 1, which shows in relative yields, the annual crop for each treatment. Each bar represents the average crop on 10 plots. For any particular year, the value of 100 represents the average yield of the 50 fertilized plots during that year.

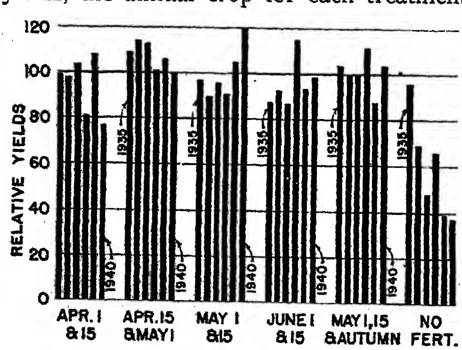

Fig. 1. Yield of blueberries with different dates of fertilizer application.

The most striking feature of Fig. 1 is, of course, the rapid and great decline in production on the unfertilized plots. For the last four years, the unfertilized plots have averaged 47½ per cent of the crop on

TABLE I—AVERAGE BLUEBERRY YIELDS (OUNCES PER PLANT) 10 REPLICATIONS EACH TREATMENT

Year	Yields With Various Dates of Application					No Fertilizer	Coefficient of Variation
	Apr 1 and 15	Apr 15 and May 1	May 1 and 15	June 1 and 15	May 1 and 15 and Autumn		
1935	66	73	65	59	70	64	17.3
1936	30	33	26	27	29	20	29.6
1937	79	87	74	67	77	37	24.7
1938	110	137	125	156	152	90	32.0
1939	71	70	69	62	58	26	30.2
1940	56	73	87	72	76	27	32.5
5-Year Means, 1936 to 1940							
Ounces per plant*	69	80	76	77	78	40	—
Bushels per acre	101	117	111	113	114	59	—

*Standard deviation of any one mean 10.5 ounces.
Standard error of difference between two means 6.6 ounces.
Difference required to show odds greater than 19:1 13.77 ounces.

the fertilized plots. It is also notable that in the first year, 1935, the production of the unfertilized plots was normal, as indicated by the relative value of 96. This is to be expected, since the crop matures early in the season and is determined largely by the food reserves in the fruiting laterals. During the first year that a plant is left unfertilized, the ripening crop absorbs most of the energies and resources of the plant; usually a good showing is made in terms of fruit but the wood and food reserves produced are sufficient only for a poor crop in the following season. With the earliest treatment, April 1 and 15, there has been a downward trend in spite of the large yield in 1939. With the second early treatment, April 15 and May 1, there has been little change in relative productivity. This is likewise true for the autumn combination. With the two middle treatments there has been some improvement in production. Of the five fertilizer treatments, the earliest is the only one which appears at a disadvantage.

Table I presents the annual average yields obtained in ounces per plant and the 5-year means for the years 1936 to 1940. Transposed to bushels per acre, these 5-year means range from 101 to 117 bushels for the fertilized plots and 40 bushels for the unfertilized. Beginning with the second year of the experiment, the coefficient of variation is fairly uniform. Since the first year yields could not show the effect of treatments, they were dropped from consideration, and the remaining averages were treated as five replications of the various treatments. Analysis shows that the standard deviation for any 5-year mean is 10.5 and the standard error of the difference between two 5-year means is 6.6. Using Fisher's table of t, we find that if the odds are to be 19 to 1 against a difference being due to chance, such a difference must be greater than 13.77 ($n = 20$ and $t = 2.086$).

The very low yield obtained with the "no fertilizer" treatment is highly significant and leaves no room for doubt as to the importance of fertilizer.

The greatest difference between fertilized plots occurs between the two earliest treatments. In 1938 this difference was 27 ounces and

in 1940 it was 17 ounces. In 1939, however, the yields were practically identical, and in 1936 and 1937 the differences were small. The difference between the 5-year means is 11, the odds being 9 to 1 that this is not due to chance.

Over a period of five years, then, no one fertilizer treatment has resulted in significantly higher yields than any other.

The April 1 and 15 treatment produced yields low enough to serve as a caution against fertilizing on a commercial scale before April 15. Since the buds usually break open during the latter half of April, it is possible that the second portion of this treatment could be well utilized while only the first portion was too early.

Conclusions

New Jersey blueberries may be fertilized to good advantage at any time during the period April 15 to June 15.

When the year's quota of fertilizer was divided into three equal parts, the last being applied in October, yields obtained were as good as those on plots receiving the full fertilizer in the spring.

During the last 4 years of the experiment, the plots receiving complete fertilizer produced twice as much fruit as the plots receiving no fertilizer.

Effect of Mulches and Fertilizers on Yield and Survival of the Dryland[1] and Highbush[2] Blueberries[3] [4]

By Amihud Kramer, E. L. Evinger, and A. L. Schrader, *University of Maryland,* and *Soil Conservation Service, College Park, Md.*

THE culture of horticultural varieties of the highbush blueberry, *Vaccinium corymbosum* (L.), has been receiving considerable attention for the past three decades. However, there has been practically no work done with the dryland blueberry, *V. vacillans* (Torr.). There are thousands of acres of natural stands of dryland blueberries throughout the south and central regions of the Atlantic Coast.

This latter species, because of its low and spreading type of growth, is a valuable plant from the standpoint of soil conservation and also as a source of supplemental farm income. This experiment has, therefore, been undertaken in order to find a method by which this species may be readily transplanted, and also, to find some treatment that might increase the yield of marketable fruit and at the same time give maximum protection against soil erosion.

Materials and Methods

Thirty-six blocks, 33 by 26.4 feet each, were laid out in the form of a Latin square. In March 1939, four rows of dryland blueberry plants and one row of named varieties of highbush blueberries were planted in each block. Each row consisted of eight plants, spaced 3.3 feet apart, and the rows were 6.6 feet apart, so that each plant occupied an area of one half millacre. The row of highbush plants consisted of four 2-year-old plants of the Pioneer variety, alternating with four plants of the Concord variety.

After planting, the following treatments were applied in each block: the horticultural varieties and one of the dryland blueberry rows received a fertilizer application of 5–10–5 (N–P_2O_5–K_2O) at the rate of 400 pounds per acre. Another row was treated with ammonium sulphate at the rate of 100 pounds per acre, while in a third row, the kind of mulching material that was to be used in the block was placed in trenches on either side of the plants. The remaining row in each block remained untreated.

The fertilizer treatments were applied in June 1939, and repeated in June 1940. In May 1939, four mulching materials were placed on some of the blocks, six replicate blocks being used for each material, the blocks being chosen by randomization, modified to suit the Latin square arrangement. The several materials were: horticultural peat

[1]*Vaccinium vacillans,* or as it is recently being called, *V. pallidum.*

[2]*Vaccinium corymbosum.*

[3]A cooperative study by the Department of Horticulture, University of Maryland, and the Hillculture Division, Soil Conservation Service, United States Department of Agriculture, Scientific Contribution No. 526, Maryland Agricultural Experiment Station.

[4]The work on these plots was carried out by T. A. Alexander during the season of 1939.

TABLE I—SOIL MOISTURE, ACIDITY, ORGANIC AND AVAILABLE MINERAL CONTENTS AS AFFECTED BY MULCH APPLICATIONS (MAY 25, 1939)

Mulch	pH	Ca*	Mg*	Al*	Fe*	No₃*	NH₄*	P*	K*	Mn*	Organic Matter (Per Cent)	Moisture (Per Cent)
Check	4.5	2	2	32	6	6	6	0	5	6	0.6	10.91
Peat-sawdust	4.5	4	3	30	10	6	6	0	4	10	1.2	18.33
Pine leaves	4.7	4	4	28	10	6	6	0	4	14	1.1	19.83
Oak leaves	4.7	2	5	32	10	6	6	0	6	12	1.1	19.71
Straw	4.6	1	1	28	8	6	6	0	5	11	0.7	18.44
Lespedeza cover	4.8	4	5	30	6	6	6	3	3	6	0.8	11.22

*Totals for six replicates; values obtained by converting "trace" to 1, "low" to 3, "medium" to 5, and "high" to 7.

covered with sawdust to keep the peat from blowing off, pine leaves, oak leaves, and straw. Annually reseeding lespedeza was planted in one set of blocks, and another set of blocks was left as a clean cover check.

Soil samples were taken in May 1939, before fertilizer treatments were applied, in July, after fertilizer application, and again in September 1940. Soil moisture was determined, and quick tests of mineral nutrients and organic matter were made by the University of Maryland Soils Department in the laboratory of R. P. Thomas. A record was taken of the number of plants surviving in each row in June 1940. Data on yield and number of bearing plants were obtained in July 1940.

RESULTS

A summary of the soil data before fertilizer application in 1939 is given in Table I, and after fertilizer application in Table II. The soil acidity is expressed in pH, and soil moisture and organic matter on a per cent basis. The quantities of available mineral elements were described as absent, trace, low, medium, or high. In order to facilitate tabulating and summarizing of the data, these descriptive terms were converted into numerical values. Thus, trace was ascribed the value of one; low, three; medium, five; and high, seven. The total of values obtained for the six replicates of each treatment were placed in the tables.

TABLE II—SOIL MOISTURE, ACIDITY, ORGANIC AND AVAILABLE MINERAL CONTENTS AS AFFECTED BY MULCHES AND FERTILIZERS (JULY 28, 1939)

Mulch	pH	Ca*	Mg*	Al*	Fe*	No₃*	NH₄*	P*	K*	Mn*	Organic Matter (Per Cent)	Moisture (Per Cent)
Check	4.5	4	5	30	6	6	6	6	3	12	1.0	11.19
Peat-sawdust	4.6	6	4	26	8	6	6	6	1	24	1.0	18.72
Pine leaves	4.6	6	6	26	12	6	6	6	3	22	1.2	18.18
Oak leaves	4.7	5	7	26	12	6	10	6	3	20	1.1	18.22
Straw	4.7	5	7	26	12	6	10	6	0	19	1.0	17.92
Lespedeza cover	4.5	6	6	30	6	10	16	6	8	20	0.9	8.53
5–10–5	4.7	6	6	26	10	8	10	6	3	24	0.9	—
Ammonium Sulphate	4.5	5	5	26	14	6	20	6	2	24	1.0	—
Mulch trenched	4.6	6	6	26	6	6	6	6	2	10	1.5	—
Mulch only	4.7	6	6	24	16	6	6	6	1	18	1.0	—

*Total for six replicates; values obtained by converting "trace" to 1, "low" to 3, "medium" to 5, and "high" to 7.

TABLE III—Soil Moisture, Acidity, Organic Matter, and Available Mineral Contents as Affected by Mulches (September, 1940)

Mulch	pH	Ca*	Mg*	Al*	Fe*	NO_3*	NH_4*	P*	K*	Mn*	Organic Matter (Per Cent)	Moisture (Per Cent)
Check	4.0	0	2	30	14	8	30	0	0	14	1.1	12.76
Peat	4.1	0	0	34	18	6	30	0	0	22	0.9	18.21
Pine	4.0	0	0	30	22	4	26	0	0	10	1.4	17.73
Oak	4.2	0	8	26	34	6	26	0	0	18	1.6	20.39
Straw	4.3	0	2	34	26	6	30	0	0	22	0.8	16.95
Lespedeza	4.0	0	2	34	10	4	30	0	0	18	1.0	13.71

*Totals for six replicates.

Soil acidity was apparently little affected by mulches or fertilizers. Soil moisture was approximately the same under all the mulches, although almost double the moisture content of the clean cultivated blocks. Soil moisture under the lespedeza cover was even lower than in the check blocks.

In regard to the mineral content (Tables I, II), calcium and magnesium, which were less than a trace, were only slightly increased after fertilizer application. Aluminum, iron, and nitrogen were little affected, while there appeared to be an increase in phosphorus and manganese, and an actual decrease in potassium, between May and July of 1939. Nitrate, ammonium nitrogen and potassium content of the lespedeza plots were apparently increased by the addition of the fertilizer. Ammonium sulphate application increased the ammonium content of the rows to which it was added, but addition of the complete fertilizer had little effect on the content of the rows so treated.

Soil data for the samples taken in September 1940, are given in Table III. Apparently, during the elapsed period of 14 months since the previous set of samples was taken, the pH value was lowered, and

TABLE IV—Plant Loss of Horticultural Varieties of Highbush and Native Dryland Blueberries, as Affected by Mulch and Fertilizer Treatments

Treatments	Mulches					
	Clean Cover	Peat	Pine	Oak	Straw	Lespedeza
	(Number of Plants Lost of a Possible 48)					
Horticultural varieties	1	2	2	9	4	4
Dryland blueberries						
Mulch only	3	13	24	25	21	9
Mulch trenched	1	1	15	24	25	4
Ammonium sulphate	5	18	14	24	25	5
Complete 5–10–5	7	19	21	23	34	12
Difference required for significance 5.16†						
F values for:						
Mulches 21.54**						
Treatments 16.03**						
Replicates (east-west) 1.72						
Replicates (north-south) 4.18**						

†Greatest standard deviation between any two of the mean values in the table, times two was 10.5; therefore, if the variance method of analysis is not considered valid, since data are discreet, there yet remain many significant differences.
*Significant beyond the 5 per cent point.
**Significant beyond the 1 per cent point.

along with it, the available calcium, magnesium, potassium, and phosphorus approached the vanishing point, regardless of treatment. Soil moisture remained essentially the same, while available ammonium increased to a remarkable extent, indicating that reduction processes were predominant in the soil.

The survival of the plants is shown in Table IV, as the number of dead plants out of a possible total of 48. The survival of the horticultural varieties was comparatively good under all conditions, since only a total of 22 out of 288 plants failed to survive until June 1940. Oak leaf mulch caused a significant increase in the number of dead horticultural plants.

The survival of the dryland blueberry plants was significantly affected both by the mulch and the fertilizer treatments. All four mulching materials significantly reduced survival, and additions of complete fertilizer to the peat and straw mulches tended to further decrease survival. Trenching of pine leaves in the root zone and addition of ammonium sulphate improved plant survival under the pine leaf mulch, but there still remained a lower survival than the survival of the check or lespedeza blocks. Practically all loss of plants, however, was eliminated when peat was trenched into the root zone.

The number of bearing plants (Table V) was closely related to the number surviving. Thus, the greatest number of bearing plants was found in the check and lespedeza blocks.

Since the check blocks contained by far the greatest number of bearing plants, the yield of the check plots of the horticultural varieties (Table V) was not significantly different from the yield of the peat mulched plots, and significantly higher than the yield of the mulch treated plots. However, when the yields were adjusted by the use of analysis of covariance, for variations in the number of bearing plants, it became evident that independently of the number of bearing plants, the yield of the peat mulched plots was more than 100 per cent higher than the yield of the check plots; and that pine, oak, and straw mulches resulted in higher, though not significantly higher yields than the check plots, and only the lespedeza plots gave a lower yield than the clean cover check plots.

The yield data of the dryland blueberry plants show similar results in response to the mulches, but the yields were too low to receive much emphasis.

TABLE V—Yield in Ounces of Horticultural Varieties of Highbush Blueberries as Affected by Mulches and Fertilizer Treatments

Mulches	Yield	Plants Bearing	Yield Adjusted By Covariance
Check	89.0	39	40.7
Peat	84.3	19	91.8
Pine	58.2	21	60.2
Oak	10.2	9	45.7
Straw	47.9	19	55.4
Lespedeza	32.2	23	28.6
Difference required for significance	—	—	30.14
"F" mulches	—	—	3.83*

*Significant beyond the 5 per cent point.

From the soil erosion standpoint, lespedeza cover and the peat-sawdust treatments were most effective, while the clean cover check allowed considerable loss of soil.

Discussion

The apparently paradoxical results of the inverse relation between survival and yield are difficult to understand. It is possible that the tremendous increase in organic matter applied in the form of the mulch material caused temporary nitrogen starvation which in turn caused early loss of plants. If such were the case, then the application of nitrogen carrying fertilizers should have corrected the situation. The not-significant improvement in survival effected by the application of ammonium sulphate to the pine mulched rows might indicate that the quantity of nitrogen applied was insufficient to entirely overcome the condition of nitrogen starvation early in the season.

Darrow and Magness (3), who obtained a large improvement in stand as well as in cane growth and yield of red raspberries as a result of straw mulch applications, added 600 pounds per acre of nitrate of soda in two applications each year.

Applications of complete fertilizers in 1939, however, if they had any effect at all, tended to decrease survival. It may possibly be that certain toxic substances in the mulch materials were released, and caused the higher mortality among the dryland blueberry plants. Support for such a possibility may be found in the work of Midgley and Dunklee (7) who reported that acid soils became toxic when limed because the tannins present in the organic matter became activated. Additional Vermont work (4) indicates that most woods, litters, straws, manures, and even peat moss, when treated with strong acids, release toxic substances. These toxic materials appear to be definitely related to the organic fraction of the soil, and their effect is independent of organisms, since the toxicity persists in sterilized soils. Crops in the seedling stage are most seriously affected.

If similar forces become active upon the additions of large quantities of organic matter in the form of mulch on soils of high acidity, then it becomes probable that the dryland blueberry plants used in this experiment were primarily affected during a short period following their transplanting, but after once becoming established, the better moisture conditions (Tables I, II) and perhaps a more favorable soil temperature (3) existing under the mulches resulted in higher yields of the plants that survived the transplanting period.

In view of the above, the improvement in both survival and yield obtained upon trenching some of the mulching materials alongside the root zone might be explained by the probability that the toxic materials of the organic matter leached down, rather than laterally, so that the toxic materials from the mulch on the surface leached down into the roots, while similar materials from the trenched organic matter did not come into direct contact with the roots, but did improve moisture conditions, and perhaps gradually supplied the plants with more available nutrients, and possibly phytohormones.

The negative effect of fertilizer application on survival, and the

accumulation of ammonium, observed in this experiment, and also the results of Beckwith, Coville, and Doehlert (1) that led them to warn against too generous fertilization of newly planted fields, indicate that not only the quantity but also the source, time and method of application of the fertilizer are important in obtaining favorable responses in the form of blueberry plant growth and yield.

The peat-sawdust mulch gave significantly higher yields than the other mulches. This may be due, in part at least, to the calcium, sulphur, and boron, which may be present in the peat in an available form (5).

Preliminary root measurements indicate remarkable differences in root distribution under the peat mulch in contrast to plants under no mulch. The lateral root spread from the main stem of plants under peat averaged 32 inches and was limited almost entirely to the 3-inch layer of the mulch itself, while the lateral spread of the check plants averaged only 12 inches, but the roots penetrated to a depth of 9 inches. Such a condition indicates that the peat mulch, and the other mulches to a lesser degree, would be instrumental in checking soil erosion at first by their presence, and later by the network of blueberry roots which developed more rapidly, and over a wider area than the roots of plants not mulched.

The decrease in pH and the decrease to the vanishing point of available calcium (compare Tables II and III), together with the knowledge that peat is a source of available calcium (5, 9), and that there probably was a lack of aeration which resulted in the accumulation of ammonium, all point to the probability that blueberry plants grown on the soils used in this experiment would benefit from lime application. Such a conclusion is in agreement with Chandler's (2) results, and in contrast to the results of Merrill (6).

Summary and Conclusions

Horticultural varieties of the highbush blueberry *Vaccinium corymbosum,* and naturally occurring plants of the dryland blueberry *V. vacillans* were planted in a 6 by 6 Latin square on acid silt loam soil at Beltsville, Maryland. Six mulching and cover crop treatments and four fertilizer treatments were applied in the spring of 1939, and the fertilizer treatments were repeated in the spring of 1940. Data that were obtained on soil conditions, yield, and survival of the blueberry plants were treated by the analysis of variance and covariance methods, with the following significant results: applications of mulch decreased the survival of the dryland blueberries but increased the yield of the highbush blueberries and dryland blueberries. Peat mulch in particular increased yield and root spread. Ammonium sulfate and complete fertilizer had little effect on improving survival, but did improve yield. Trenching of the mulching material, especially peat, alongside the root zones, greatly improved survival and yield. Peat-sawdust mulch, and lespedeza cover gave the best control of soil erosion. The lespedeza cover, however, reduced the yield of blueberries.

In view of the above results the following procedure may be recommended: upon transplanting, some organic material, preferably peat,

mixed with a small amount of nitrogen carrying fertilizer (nitrate, if the soil is acid) should be trenched in around the roots (possibly mixed with the soil as suggested by Tukey and Brase (8)), but not in direct contact with them. After the plants have become established and made some new growth, a mulch, preferably peat, should be applied. Complete fertilizer may then be added.

The above procedure would modify the usual practice of applying mulch and fertilizer directly after transplanting.

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The Effect of Soil Temperature on the Growth of Cultivated Blueberry Bushes[1]

By JOHN S. BAILEY and LINUS H. JONES, *Massachusetts State College, Amherst, Mass.*

SOIL temperature has been shown to have several important effects on the growth of plants. For good reviews of the subject see Jones (4) and Kramer (5). Among the effects reported is a reduction of growth rate and the appearance of a chlorotic condition of Gardenia at low soil temperatures (4). Since a similar chlorosis appears at times on cultivated blueberries (1), it seemed possible that this blueberry chlorosis might be related to soil temperature. Also, there might be other effects.

Accordingly, an experiment was set up in the soil temperature apparatus used by Jones (4) and described by Fuller and Jones (3). The plants used were 3-year-old nursery grown Rubel plants. Sixty-five of these plants were dug in November, 1939, potted in 6-inch clay pots, and placed in a storage cellar at about 40 degrees F to go through the rest period. On February 19, 1940, 32 uniform plants were selected and transferred to the containers of the soil temperature apparatus, using soil from the nursery where the plants had grown. All weak wood and fruit buds were removed. The soil temperature was held at 70 degrees F for 2 weeks until the plants had had a chance to establish themselves in their new environment. On March 4, 1940, the temperature in the temperature tanks was adjusted to give the following series of soil temperatures: 90, 85, 80, 75, 70, 65, 60, and 55 degrees F. Four plants were used at each temperature. The air temperature, although it increased considerably on bright sunny days, was held most of the time near 70 degrees F. The experiment was continued till June 19, 4 months, when the height and total linear growth of the plants were measured and the experiment discontinued.

The first noticeable result was the wilting of the plants at the two lower temperatures, particularly those at 55 degrees F which wilted within 2 hours after the temperature of the water in the temperature tanks was changed. After a few days the plants became adjusted to the new soil temperature and stopped wilting. This phenomenon has been reported by Jones (4) and Kramer (5).

Although a chlorosis similar to that mentioned above (1) appeared on some plants a month after the experiment was started, its relation to soil temperature was not marked; there was only a slight suggestion of more chlorosis below 70 degrees F than above it.

The plants at soil temperatures below 70 degrees F were slower in starting than those above. This is shown in Table I by the average number of growing points which had started per plant on March 8, 4 days after the differential soil temperatures were set up. The average number of growing points started above 70 degrees F is variable but consistently higher than the average number started below 70 degrees F.

[1]Contribution No. 397 of the Massachusetts Agricultural Experiment Station.

TABLE I—GROWTH OF BLUEBERRY PLANTS IN SOIL TEMPERATURE TANKS (1940)

Temperature (Degrees F)	Average No. of Growing Points Started Per Plant, Mar 8, 1940	Average Height Per Plant (Inches)	Average Total Linear Growth Per Plant (Inches)
55	3.25	14.7	30.3*
60	3.75	18.0	44.1
65	5.75	16.7	43.8*
70	6.25	26.2	58.0
75	9.00	26.7	71.8*
80	6.25	30.0	73.9
85	9.50	37.7	84.1
90	7.50	34.0	88.0*

*Three plants in these averages instead of four, one plant died.

Soil temperature greatly influenced total linear growth and height of the plants as shown by the results in Table I and Fig. 1. The higher the temperature, the greater is the total linear growth. Height of the plant also increases as the soil temperature increases. This correlation is apparently not so good as that for total linear growth. Since the height of blueberry plants is not a very good measure of their response to any treatment, this is to be expected.

That the growth of blueberry plants should be correlated with soil temperature agrees with the results of other workers in this field. Jones (3) reported that both growth rate and leaf size of *Gardenia veitchii* are correlated with soil temperature. Batjer, Magness, and Regeimbal (2) reported reduced growth rate and reduced total linear growth of apple trees at low soil temperatures.

Although it is not shown by the figures, there appeared to be a change in the type of growth between 65 and 70 degrees F. Plants growing at a soil temperature of 70 degrees F or above tended to be tall and upright; plants growing at a soil temperature of 65 degrees F or below tended to be short and spreading.

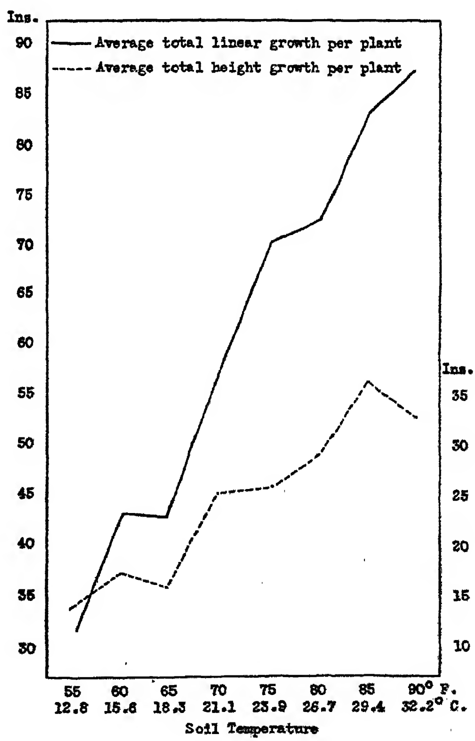

FIG. 1. Effect of soil temperature on the height and linear growth of cultivated blueberry bushes.

As a result of growing Rubel blueberry plants at a series of soil temperatures from 55 to 90 degrees F, (a) the plants at 55 and 60 degrees F first wilted but shortly recovered; (b) both total linear growth and height were found to be related to soil temperature; and (c) plants above 65 degrees F seemed to grow tall and upright; those at 65 degrees F and below, short and spreading.

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The Effect of Lime Applications on the Growth of Cultivated Blueberry Plants[1]

By J. S. BAILEY, *Massachusetts State College, Amherst, Mass.*

FOR a number of years after Coville (3) laid the foundation for blueberry culture, it was assumed that lime was detrimental to the growth of blueberries. Johnston (4) showed that they grow best in a very acid sand or muck at pH 4.4. More recently Chandler (2) and Merrill (5) reported that under the conditions of their experiments lime was beneficial to blueberries. That this is not always so will appear from the results of these experiments.

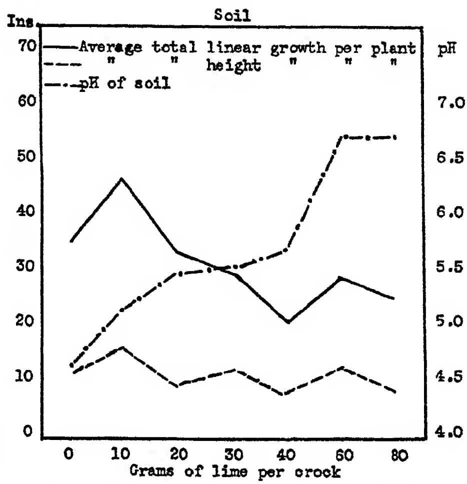

FIG. 1. Effect of lime on the soil pH and growth of blueberry plants—1935.

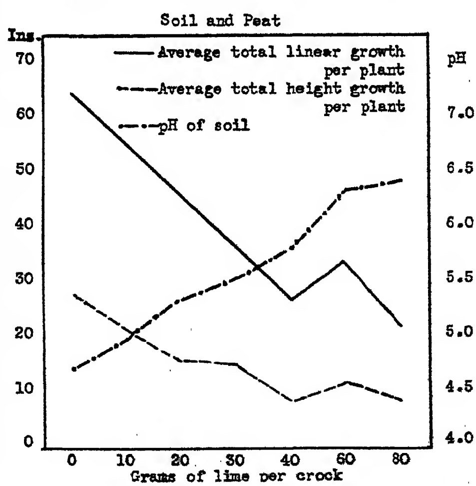

FIG. 2. Effect of lime on the soil pH and growth of blueberry plants—1935.

On May 11 and 12, 1934, two series of experiments were set up using 3-gallon glazed earthenware crocks. The soil used was a Merrimac fine sandy loam with a pH of 4.6. The crocks in series 1 were filled with 17 kilograms of soil; those in series 2 with 14.5 kilograms of a mixture of 95 per cent soil and 5 per cent (by weight) of German peat, Grade GPM. Each series was divided into seven treatments of three crocks each and the soil treated with lime; 0, 10, 20, 30, 40, 60, or 80 grams per crock. The soil for each crock was weighed separately, the desired amount of lime mixed thoroughly with it and it was then placed in the crock. A 2-year-old Ru-

[1]Contribution No. 398 of the Massachusetts Agricultural Experiment Station.

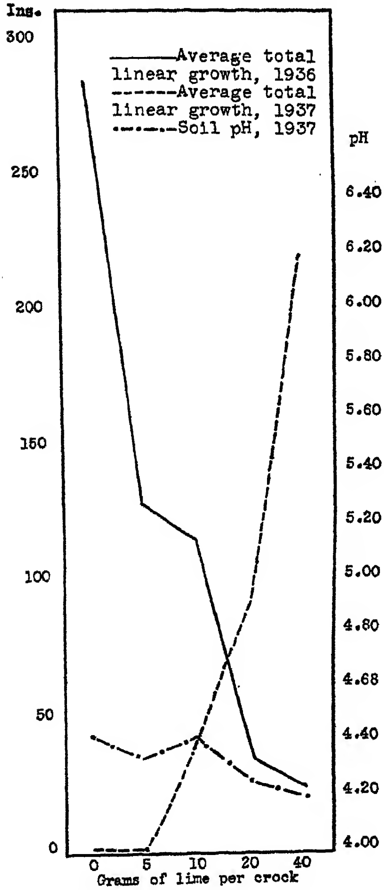

FIG. 3. Effect of lime on soil pH and growth of blueberry plants.

bel plant was set in each crock. Probably due to cold injury the preceding winter, most of these plants died so all plants were replaced May 10, 1935.

Table I shows the change in pH and the average total linear growth and average height growth per plant in inches after one year's growth. These results are shown graphically in Figs. 1 and 2.

In the spring of 1936 this experiment was discontinued and another set up. The same type of soil from the same source was again used in 3-gallon glazed earthenware crocks. This time 10 kilograms of soil were used per crock and 1 3-year-old Rubel plant was set in each crock. A series of lime treatments, five crocks per treatment, was set up as follows: 0, 5, 10, 20, and 40 grams of lime per crock. In these experiments the lime was again thoroughly mixed with the soil. In the spring of 1937 each crock received 1 gram of nitrate of soda. The results are presented in Table II and Fig. 3.

The first visible result of the lime applications was the appearance of chlorosis similar to that reported in 1937 (1). All the limed plants showed at least a little chlorosis, which increased slightly with time and considerably with increase in the amount of lime.

The results show without question that under the conditions of these experiments (a) lime was detrimental to growth of cultivated blueberries and (b) the addition of 5 per cent of peat to the soil reduced slightly the bad effect of the lime. It is interesting to note in Table II that although 5 grams of lime did not increase the soil pH permanently above that of the unlimed soil, the lime reduced the growth of the plants by 55 per cent.

Although these experiments do not deal with surface applications of lime, they do suggest that after the lime has become fully effective undesirable results may follow heavy surface applications.

TABLE I—EFFECT OF LIME ON THE SOIL pH AND GROWTH OF BLUEBERRY PLANTS (1935)

Grams of Lime Per Crock	Lime (Pounds Per Acre)	Soil pH Oct 23, 1935	Average Total Linear Growth Per Plant (Inches) 1935	Average Total Height Growth Per Plant (Inches) 1935
		Soil		
0	0	4.60	35.3	11.7
10	1176	5.20	42.0	18.3
20	2352	5.50	34.3	10.0
30	3528	5.55	31.7	13.3
40	4704	5.75	21.7*	9.0*
60	7056	6.75	29.5*	13.0*
80	9408	6.75	25.0	9.3
		Soil and Peat		
0	0	4.80	64.7	28.0
10	1379	5.00	56.0	21.7
20	2756	5.30	46.0	16.0
30	4137	5.70	35.7	15.0
40	5512	5.95	26.7	9.7
60	8274	6.45	34.3	11.7
80	11024	6.65	22.0	9.3

*One plant died.

TABLE II—EFFECT OF LIME APPLICATIONS ON SOIL pH AND GROWTH OF BLUEBERRY PLANTS (1936 AND 1937)

Grams of Lime Per Crock	Pounds of Lime Per Acre	Soil pH June 26, 1936	Soil pH August 21, 1936	Soil pH July 15, 1937	Average Total Linear Growth Per Plant (Inches)	
					1936	1937
0	0	4.55	4.60	4.02	43	284
5	1000	5.00	4.80	4.02	35	129
10	2000	5.30	5.40	4.39	41	115
20	4000	6.30	6.30	4.94	26	37
40	8000	7.25	7.10	6.20	21*	26*

*Only two plants lived.

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Chromosome Numbers of Some Species and Varieties of Vaccinium and Related Genera[1]

By Earl H. Newcomer, *Michigan State College, East Lansing, Mich.*

With the exception of the work of Coville (1, 2) and Longley (4) in this country and a few scattered papers by Scandinavian workers, there seems to have been little done in the cytogenetics of the cultivated blueberry and related species and genera. Since an active breeding program has been in operation for the past 25 years and although many desirable new selections and hybrids have been introduced, a more extensive cytogenetic and taxonomic investigation of the group would seem to be indicated for the elucidation of present problems as well as for the possible opening of new fields or the suggesting of new directions for future breeding work.

The genus Vaccinium apparently consists of a series of eupolyploid species with a basic genom of 12, or perhaps six chromosomes. Interspecific compatibility is variable and is usually, but not always, determined by chromosome number, as Longley has shown. With tetraploidy the group seems to have reached its optimum in range, with the exception of *Vaccinium uliginosum,* which extends into the Arctic and is circumpolar in distribution, and is apparently a diploid form (3), although closely associated with a tetraploid variety of the species.

The present study constitutes a survey of materials which were rather readily available and is preliminary in nature, observations being largely limited to the chromosomes of the meiotic metaphases. Counts were made on many of the commercially grown varieties and hybrids of *V. corymbosum,* in an effort to learn whether aneuploidy or any other gross chromosomal aberrations could be correlated with the very obvious varietal distinctions within the species. The type and degree of pairing were observed for possible information on genotypic relationships.

Materials and Methods

The varieties of *Vaccinium corymbosum, V. pennsylvanicum* and *V. atrococcum* used in this study were obtained from the South Haven Experiment Station of Michigan where they are under cultivation. The other species of Vaccinium and related genera were collected in the wild from North Carolina and Tennessee. Buds were fixed in Carnoy's solution and dissected and smeared by the aceto-carmine method.

Results

Five selections of *Vaccinium pennsylvanicum,* L. B. Nos. 1, 4, 25 (forma *leucocarpum*), 34, and 35, were found to have 24 pairs of chromosomes, and pairing and disjunction were regular in all cases.

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[1]Journal Article No. 496, N. S., of the Michigan State College Experiment Station.

TABLE I—VARIETIES OF *Vaccinium corymbosum* (CHROMOSOME NUMBER 24)

Variety	Origin	Remarks
Stanley	F_1 of Katharine×Rubel*	Secondary pairing
Jersey	F_1 of Rubel×Grover*	Normal
Weymouth	F_1 of June×Cabot*	Secondary pairing, lagging
Adams	Wild selection	Normal
Taylor	Michigan selection	Normal
Rubel	Wild selection*	Normal
Kahler	Michigan selection	Normal
Schigner	Michigan selection	Normal
Cabot	F_1 of Brooks×Chatsworth*	Normal
Dunfee	Wild selection	Secondary pairing, lagging
Cabot×Pioneer	South Haven	Normal
Adams×*Vaccinium pennsylvanicum* (L. B. No. 4)	South Haven	Secondary pairing, lagging
Rancocas	(See Discussion, below)	Ring chromosomes

*The origin of varieties marked by * is taken from the work of Coville, who did so much for the improvement of the wild blueberry.

TABLE II—SPECIES OF VACCINIUM AND RELATED GENERA

Species	Chromosome Number	Genus and Species	Chromosome Number
Vaccinium		*Related Genera*	
V. atrococcum (var. Orvis Williams)	24	*Gaylussacia baccata*	12
V. Vitis Idaea	12	*Bruckenthalia spiculiflora* (Benth.)	18
V. stamineum	12	*Gaultheria procumbens*	12
V. oxycoccus	36		
V. vacillans	12		

DISCUSSION

Coville gives two slightly divergent accounts of the origin of Rancocas (1, 2). It is either an F_2 plant of *Vaccinium angustifolium* x *V. corymbosum* or an F_1 of (Brooks x *V. angustifolium* var. Russell) x Rubel. The meiotic chromosome behavior of Rancocas reflects its interspecific origin. At metaphase a ring of four rather loosely associated chromosomes was common, and catenate or zig-zag separation at anaphase frequent, indicating a greater degree of structural hybridity than expected or observed in purely varietal hybrids. Despite these meiotic aberrations, normal-appearing and apparently functional gametes were formed, indicating a high degree of homology between the respective genoms.

Longley reported *Vaccinium atrococcum* as a 12 paired species and Coville described it as incompatible or very weakly compatible with *V. corymbosum*. If the number of 12 chromosomes is confirmed for this species, it is apparent that the *V. atrococcum* variety Orvis Williams used in this study is a tetraploid. As such it may prove useful in combination with *V. corymbosum* or any other 24 paired species. The fact that *V. atrococcum* variety Orvis Williams is a normal-appearing plant with no phenotypic hybrid characteristics precludes any theory of recent origin by allopolyploidy, and the further observation that no secondary chromosome association was observed would seem to militate against the theory of its recent origin by autopolyploidy. From these facts it must be postulated either that there are two forms of *V. atrococcum* with chromosome numbers of 12 and 24 or that in the

absence of an adequate taxonomy the investigators are confusing species.

If secondary pairing is an expression of homologies or affinities more remote than those which can be expressed in primary association, the rather general occurrence of secondary polyvalent association suggests that *Vaccinium corymbosum* is autotetraploid in origin. The apparent ease with which interspecific and, in several reports, intergeneric crosses can be made suggests a relatively recent phylogenetic origin for a large section of the family. This is further supported by the almost normal behavior of the chromosomes in the single F_1 individual of an interspecific hybrid investigated.

Since amphidiploidy seems to offer greater possibilities than autopolyploidy from the point of view of wider adaptability, variety, and so on, and since the conditions requisite for the occurrence of amphidiploidy, *i. e.*, well differentiated genoms, are apparently absent in the cultivated species of Vaccinium, perhaps wider ranges of hybridization should be attempted if a blueberry more tolerant to wider climatic and soil conditions is to be achieved. A factor favoring the attempt to induce genetic unbalance less than that causing sterility is that propagation can be effected asexually. Any program, however, requiring successive crossings is handicapped by the length of time required for the development of the blueberry from seed to fruit production.

Summary

The chromosome number of the variety *Vaccinium atrococcum* used in this study was 24 pairs and not 12, as had been previously reported. The evidence suggests that this selection is not a recent polyploid form. Chromosome pairing in *V. corymbosum* suggests an autopolyploid origin and the analysis of hybrids between *V. corymbosum* and other species of the genus shows a high degree of homology and therefore a comparatively recent origin from a common ancestor. No aneuploidy or chromosome aberrations were observed in any of the varietal types of *V. corymbosum.* The suggestion is made that hybridization be attempted on a wider range than has been currently practised.

The basic chromosome number of Vaccinium has been assumed to be 12 and no evidence from this study suggests a lower basic number. The significance of the chromosome number of 18 in Bruckenthalia, an introduced European genus, is not known, in the absence of data on breeding behavior.

It is a pleasure to acknowledge the assistance of Mr. Stanley Johnston, Superintendent of the South Haven Experiment Station, in procuring the materials of the cultivated blueberries, and of my former student, Mr. Albert Johnson, in the collections from North Carolina and Tennessee.

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The Limitations of Chaenomeles Lagenaria Wilsonii as a Horticultural Plant[1]

By GEORGE L. SLATE, *N. Y. State Agricultural Experiment Station, Geneva, N. Y.*

IN 1928 Lathrop (1) suggested that the Japanese flowering quince might be of value as a source of 1-malic acid for commercial fruit products. My attention was directed to a large fruited form known as *Chaenomeles lagenaria Wilsonii* and seedlings were raised with the intention of selecting superior types.

Seeds were secured from plants in the Rochester, New York park system in the fall of 1928 and again in the fall of 1930. The 1928 seeds yielded 69 plants which were set in the field in April 1931, and the 295 plants resulting from the 1930 seeds were set in the field in November 1931.

This species of quince is apparently closely related to *Chaenomeles lagenaria cathayensis,* but is more robust and wild plants attain a height of 4 to 6 meters (2). The bush is erect, open, sparsely branched and armed with vicious spines which make harvesting difficult and unpleasant. The large fruits are yellowish in color and weigh from 10 to 12 ounces each. Jelly made from them is edible, but inferior in quality to that from various other common fruits more readily available.

It does not appear that the plant is of any importance as a source of commercial pectin or 1-malic acid. Thus far the plants are lacking in hardiness and are very unproductive. The severe winter of 1933–34, during which a minimum temperature of —31 degrees F occurred at Geneva, killed all plants to the ground and all but 94 of the 1930 lot of 295 plants were killed out entirely. Nearly all of the 69 plants of the 1928 lot also perished. The survivors were all killed to the ground again during the winter of 1934–35, but since then very little winter injury has been noted.

A few fruits were produced in 1938 and 1939 and in 1940 some plants bore a dozen or more specimens. The plants appear to be very unproductive.

In view of its unproductiveness, lack of hardiness, slow growth and vicious spines this species appears to be of very limited economic value.

The ornamental horticulturist will find in its gaunt habit and the few small unattractive flowers little to attract his attention.

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[1]Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 417, Dec. 24, 1940.

Effect of Boron on Plant Growth and Dry Seed Yield in Lima Bean (Phaseolus Lunatus L.)

By Robert E. Wester and Roy Magruder, *U. S. Horticultural Station, Beltsville, Md.*

SINCE some soils of the same general type as those found on the farm of the United States Horticultural Station at Beltsville, Maryland, have been found to be low in boron, a preliminary experiment on the effect of different amounts of boron on the yield of dry seed of bush lima beans grown on a well drained level piece of Elsinboro gravelly sandy loam soil was conducted.

Materials and Methods

Seed of lima bean selection 23–6–3, having large seeds and a large bush plant, was planted by hand 12 to 15 inches apart in rows 3 feet apart on May 28, 1940. Subsequent temperature and moisture conditions were favorable for germination and a good stand was obtained.

Eight hundred pounds per acre of 2–8–10 fertilizer was drilled 1 month before planting. On May 23, 125 pounds per acre of 5–8–5 was drilled in 3 foot rows by a corn planter. A side dressing of nitrate of soda at the rate of 100 pounds per acre was applied on July 17.

On June 27, 1 week before blooming, boric acid at the rate of 5, 10, and 15 pounds per acre was applied to triplicate plots, 25 by 30 feet in size arranged randomly in each block, by spreading a sand-boric acid mixture on both sides of each row about 8 to 10 inches from the plants. On an acre basis, the boron applied was approximately 0.5, 1.0, and 1.5 parts per million, based on the surface layer of soil weighing 2,000,000 pounds. The control plots received only the washed sand. Three foot aisles separated the plots.

A rain of .42 inch, 3 days after the boric acid applications were made assured a good penetration into the soil. The 3.68 inches rainfall during July was rather evenly distributed throughout the month and resulted in good growth. August was dry (no rain) for the first 14 days and wet (4.85 inches during 10 days of rain) during the latter half of the month. September was dry with only .58 inch rain on the eighth and ninth and .93 inch on the twenty-fifth. Two rains (.83 inch on October 2 and .42 inch on October 8) occurred prior to harvest in October, but the percentage of rotted or molded beans was very low.

The plants were pulled by hand from seven inside rows on October 10 and bunches of five plants were weighed to the nearest .1 pound. Two border rows were left on the north side and one row on the south side of each plot. The plants were then spread out one layer deep in a greenhouse to dry. Practically all of the pods and beans were dry when threshed on October 21 and 22. The cleaned air-dried seed was weighed on October 23.

Three soil samples, each 7 inches deep, were taken from each plot at the time the plants were harvested and pH was determined by the Quinhydrone method.

The data were analyzed by the variance method.

Results

The addition of boric acid had no significant effect on the green weight of plants per plot, on the mean weight of 100-seed samples, or on the pH value of soil at the end of the season as shown in Table I. The increase in yield of dry seed from 5 pounds of boric acid per acre was not significant but the increases from 10 and 15 pounds per acre were significant when compared with the check plots. The highest yields of dry beans were from the plots receiving 15 pounds of boric acid per acre and were significantly greater than from any of the other treatments or the check plots.

There was no significant difference in number of plants per plot.

TABLE I—Effect of Boric Acid on Lima Bean Plants (Triplicate Plots, Beltsville, Maryland, 1940)

H_3BO_3 Per Acre (Pounds)	Mean No. Plants Per Plot*	Mean Green Weight Plants Per Plot* (Pounds)	Mean Yield Dry Seed Per Plot† (Grams)	Mean Weight of 100-Seed Samples* (Grams)	Mean Soil pH Per Plot*
None........	111	102.1	1860	86	4.88
5...........	107	103.3	2034	88	4.81
10..........	106	104.0	2236	84	4.87
15..........	111	107.1	2629	88	5.00

*No significant differences.
†Differences as great as 360 grams are significant by odds of 19:1.

Discussion

The results indicate that on this soil, the addition of boric acid just before first bloom had no significant effect on green plant weight but did have an effect on the dry weight of seed produced. The insignificant effect on plant weight is not unexpected in view of the fact that the boric acid was applied after the plants had made most of their vegetative growth. Check plants showed no apparent symptoms of boron deficiency.

The increase in yield of beans agrees with the results of Purvis and Hanna (3) who found that .5 parts per million of boron at pH 4.6 in water culture produced a good yield of pods and vines of snapbeans (*Phaseolus vulgaris* L.) while the no boron solution plants made a smaller plant growth and set no pods. Warrington (4) using Scarlet Runner bean (*P. multiflorus* L.) in water culture found that the absence of boron from the nutrient solution resulted in stunted plants whose apex blackened and died and whose lateral nodes failed to form form flower buds. Stimulation of growth was obtained over a wide range of boric acid concentrations (1:12,500,000 to 1:25,000 parts per million). The cotyledons, plumule and radicle of soaked and germinated seeds were found to contain relatively high concentrations of boron. It was also found that boron was necessary for growth and seed production in the broad bean (*Vicia faba* L.) and some other plants.

Analyses of different parts of many kinds of plants by Bobko and Zerling (1) show a high concentration of boron in the reproductive parts. These investigators also found that the addition of boron to the nutritive substrate usually increased the germination percentage of

pollen and that when applied to the soil the effect of boron was greater on the production of seeds than on total dry matter. Holly and Dulin (2) working with the cotton plant found that a shortage of boron resulted in the shedding of flowers although the shortage was not great enough to seriously retard vegetative growth.

Summary

The addition of 5, 10, and 15 pounds of boric acid per acre to Elsinboro sandy loam soil in Maryland one week before blooming caused a significant increase in yield of dry lima bean seed, but no significant increase in total green weight of plant.

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Effect of Vitamin B_1 on the Yield of Several Vegetable Crop Plants[1]

By E. C. Minnum, *Cornell University, Ithaca, N. Y.*

REPLICATED randomized field experiments were laid out during the growing season of 1940 to test the effect of vitamins added in solution on the growth of vegetable crop plants. One series of plots was located at Ithaca, New York on a silty clay loam and a second series on a sandy soil in the Albany-Schenectady area.

The main plot at Ithaca had not been manured for 7 years and had only a broadcast application of 1000 pounds of 5–10–5 in 1940. A crop of fall planted rye was plowed down in May 1940. The plots on the sandy type soil at eastern New York were not fall planted to rye and the main plot had no commercial fertilizer for seven years and very light application of manure up to 1940 when none was applied.

It was thought that if vitamins added in solution to the soil had any influence on growth that this influence might make itself more strongly felt if the vitamins were used in combination with a starter solution and an indole acid. A commercial compound containing vitamin B_1, nicotinic acid and traces of pantothenic acid, vitamin B_2 and B_6 was also included in some of the tests. Brewers yeast which contained vitamins B_1, B_2, B_4, B_6, nicotinic acid and other substances was tried in a few cases, both dry and as a thin paste made with water.

Where indolebutyric acid was used as on tomato, cabbage and pepper plants, the roots were soaked for four hours in a solution of 2 part per million just before planting. Starter solution was applied at planting time only. Vitamins in solution were added shortly after planting and at least twice thereafter. Each plant got .01 milligram of the vitamin per treatment. Where more than one vitamin was used .01 milligram of each vitamin was added. In a few cases concentrations greater than .01 milligram were used. When vitamins were applied to row crops such as radishes and beets, the vitamin solution was poured along the row of young plants shortly after they emerged.

Appropriate yield records were taken and analysis of variance applied to the data showed no significance in any case.

The growing season of 1940 in central and eastern New York was cold and wet during May and June which may in part account for the negative results obtained from the use of starter solution both at Ithaca and in the Schenectady-Albany area.

Seed of beet, squash, snap beans, and rutabaga were soaked in .01 milligram per liter of vitamins and compared with those plants treated with vitamin solutions shortly after come-up.

Conclusions

Cauliflower, muskmelons, beets, rutabagas, sweet corn, summer squash, tomatoes, snap beans, peppers, and radish were treated with

[1]Paper 227, Department of Vegetable Crops, Cornell University, Ithaca, N. Y. This work was financed by a fellowship provided by G.L.F., Ithaca, N. Y. Nopco Vitamin Laboratories of Harrison, N. J. and G.L.F. supplied certain materials for conducting these studies.

solutions of pure crystalline vitamins, a brewers yeast containing vitamins and a commercially advertised compound containing vitamins. Starter solution was used in conjunction with vitamins. The roots of some normally transplanted plants were soaked previous to planting in a solution of indolebutyric acid and treated after planting with vitamins.

Analysis of variance applied to the data showed no significance for any of the treatments applied under the conditions of the experiment.

Effect of Several Growth Substances on Vegetable Crop Plants[1]

By E. C. MINNUM, *Cornell University, Ithaca, N. Y.*

A FEW papers have appeared in the literature in which the authors have claimed stimulation of vegetable crop plants by the addition of synthetic growth substances applied either in liquid form, or combined with a suitable carrier such as talc and applied to the seed or root as a dust (3, 4, 6). Other workers (1, 7) have been unable to obtain stimulation from such substances when the plants were grown in ordinary soil.

The experiments reported here were carried out during the growing season of 1939 in an endeavor to determine the effects of synthetic growth substances on vegetable crop plants which were grown to maturity in the field. A previous report (3) dealt with the effects obtained on seedling plants, but few results were reported on which vegetable crop plants had been grown to maturity either in sand or soil. One worker (2) reported a substantial increase in yield when oat seed was soaked in a hormone solution prior to planting, but later workers have not been able to obtain such stimulation. Still other workers (5) claimed stimulation of the yield of straw when wheat seed was dusted with a phytohormone plus an organic mercury fungicide.

In order to determine the effect of the indolebutyric acid on the growth and yield of tomato plants (variety Bonny Best) grown to maturity in the field, 11 different treatments replicated five times using 10 plants per treatment were employed. The treatments consisted of soaking the roots in solutions of the acid and in dusting the roots with (a) talc alone, talc dust containing (b) 1000 (c) 2000, and (d) 4000 parts per million of the acid and (e) untreated. Appropriate check treatments were provided. Analysis of variance showed no significance for any of the treatments.

Celery plants (Golden Self Blanching) were taken carefully from the flat and the roots and soil adhering to the roots were dusted with (a) talc alone, talc dust containing (b) 1000, (c) 2000, and (d) 4000 parts per million of indolebutyric acid and (e) untreated. A second set of plants had the soil carefully washed from the roots and the roots dusted as above. Analysis of variance applied to the yield data showed no significance for any of the treatments. Apparently 4000 parts per million of indolebutyric acid applied in a talc dust to the roots was neither harmful nor beneficial to growth.

Spinach seed was treated with (a) talc alone, (b) 1000 (c) 2000, and (d) 4000 parts per million of indolebutyric in talc dust and (e) untreated by placing a sufficient quantity of the dust in a hand seeder with the seed at planting. The worm in the seed compartment of the

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[1]Paper No. 226, Department of Vegetable Crops, Cornell University, Ithaca, N. Y. Merck & Co. and Eastman Kodak Co. kindly supplied the growth substances used in these studies.

seeder kept the dust and seed well mixed. The treatment was apparently not harmful as the yields were not significantly different.

Cabbage plants (Danish Ballhead) were lifted from the seedbed and the roots carefully dusted with (a) talc alone, (b) 1000, (c) 2000, and (d) 4000 parts per million of the acid in talc and (d) untreated. They were stored overnight in a cool cellar and planted the next day. Thirty plants per treatment replicated five times were field set, of which heads of 25 consecutive plants were harvested and weighed individually for record. The yield data when subjected to statistical analysis showed the plants receiving no treatment to be slightly better than any of the other treatments applied.

Soaking sweet corn seed in a solution of indolebutyric acid of 1000 parts per million for 3 hours and dusting the seed previous to planting with the above mentioned dusts had no beneficial effect on yield of corn.

Snap bean seed was dusted with the above mentioned dusts and the yield of pods recorded. No benefit was found to result from any of the treatments.

Soaking seed of several vegetable crops in dilute solutions of indoleacetic, indolebutyric, and the potassium salts of these acids had no beneficial effect on later growth. In fact, in most cases growth was slower as a result of the soaking treatment.

Cabbage plants soaked in indole and naphthaleneacetic acids of 1, 2 and 5 parts per million for 15, 30 and 60 minutes showed no beneficial effects from the soaking.

Conclusions

Various vegetable crop seeds and plants were treated with some of the indole acids used as a dust and in solution. In no case was growth benefitted by the treatments. In some cases it was distinctly harmed.

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Probable Causes for the Difference in Facility of Producing Parthenocarpic Fruits in Different Plants[1]

By FELIX G. GUSTAFSON, *University of Michigan, Ann Arbor, Mich.*

ONE of the outstanding features of the work on parthenocarpy is the difference in ease with which different plants can be made to produce fruits by chemical stimulation. Thus tomatoes and peppers produce fruits readily, while squashes and watermelons do so only infrequently.

In this investigation two different approaches have been made. On the one hand different chemicals have been used to determine whether one chemical might be more favorable in the production of fruit with one plant, while another chemical would be more favorable with another plant, or whether a chemical which is superior with one plant is also superior with all plants. The other approach was to determine the amount of "native" auxin present in the ovaries in the flower bud stage.

A variety of plants was used: John Baer tomato, California Wonder pepper, Black Beauty eggplant, Hubbard, Buttercup and Crookneck summer squashes, Vaughn's Small Sugar Pie and Big Tom pumpkins, Jersey Improved Pickle and Vaughn cucumbers and several varieties of watermelons (Early Arizona, Stone Mountain, Dakota Sweets, Harris' Earliest, McFayden's Sweet, Favorite Honey, Burpee's Baby Delight, Sweet Siberian and Pride of Muscatine). The experiment with the watermelons was carried out during the summer of 1939 and the others during the summer of 1940 as well as 1939.

TABLE I—PERCENTAGE SETTING BY TREATMENT WITH DIFFERENT CHEMICALS

Plants Used	Indole Acetic		Indole Butyric		Naphthalene Acetic		4-Fluorene Acetic	
	No. Buds Treated	Per Cent Set	No. Buds Treated	Per Cent Set	No. Buds Treated	Per Cent Set	No. Buds Treated	Per Cent Set
Vaughn cucumber	—	—	6	0	28	0	9	0
Improved Jersey Pickle cucumber	—	—	10	0	37	3	6	0
Big Tom pumpkin*	—	—	3	0	12	0	1	0
Vaughn's Small Sugar Pie pumpkin	—	—	8	0	54	0	—	—
Hubbard squash	—	—	20	0	23	4	18	0
Buttercup squash	—	—	24	0	58	12	28	0
Crookneck summer squash	—	—	38	0**	69	30	11	0**
John Baer tomato	—	—	—	—	35	63	30	100†
John Baer tomato (1)	10	90	15	80	19	81	—	—

*One medium sized seedless fruit was produced but on harvesting the writing on the tag had been rubbed off so the chemical used could not be determined.

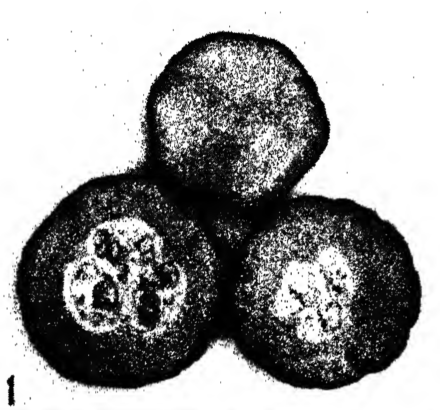
**Although no mature fruits were obtained from the treatment with indole butyric and 4-fluorene acetic acids many grew to considerable size and then rotted.

†This observation was made 2 weeks after treatment. Usually if the ovaries of the tomato begin to enlarge they continue to do so and therefore though no further observations on them were made, they undoubtedly grew into mature fruits.

[1]Paper from the Department of Botany and the Botanic Garden of the University of Michigan, No. 776.

The chemicals used were: 4-fluorene acetic (a new compound),[2] naphthalene acetic, indole acetic and indole butyric acids. These chemicals were used in 1 and 2 per cent concentrations in lanolin.

Seventy-nine ovaries of the pepper were treated with 4-fluorene acetic acid but no fruits were produced, 45 ovaries were treated with indole butyric acid and a number of fruits were produced, but unfortunately no accurate counts were obtained. Twenty-three ovaries of the eggplant were treated with 4-fluorene acetic acid, but no fruits resulted, 25 ovaries were treated with indole butyric acid and 10 with naphthalene acetic acid. With both of the latter treatments some fruits were produced but no accurate records were obtained.



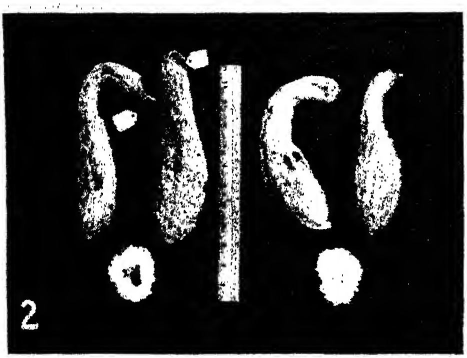


FIG. 1. Buttercup squash. The fruit at the lower left was produced by pollination and has an abundance of seeds. The other two are seedless and were produced by treating the pistil with 2 per cent naphthalene acetic acid.

FIG. 2. Crookneck summer squash. The fruits with the tags were produced by treating the ovaries with 2 per cent naphthalene acetic acid. These fruits are seedless and of normal appearance. The other two fruits were produced by pollination and are seeded.

During the summer of 1939 the watermelons were grown. From the several hundred blossoms treated only four fruits were obtained. The Harris' Earliest produced two medium sized fruits with naphthalene acetic acid. These fruits were entirely seedless and triangular in shape. The Favorite Honey produced two fruits with indole butyric acid. These fruits were of normal size and shape, and the seed coats had developed to normal size though they were entirely devoid of an embryo. No fruits were obtained with indole acetic acid.

During the two seasons determinations of the growth hormone content in the ovaries of flower buds were made on most of the plants used. The determinations were made in the usual way

[2]The writer is indebted to Mr. John C. Sheehan, of the Chemistry Department, for the 4-fluorene acetic acid.

with ether or methanol as the solvent.

In 1939 only the watermelons were used. They were extracted in the cold with ether for several periods, the last one extending over 2 months. The only ones that gave a detectable amount of hormone were the Dakota Sweet, 0.42 gamma per Kg, and the Harris' Earliest, 1.01 gamma per Kg. The Favorite Honey was not obtainable at the time the test was made.

The 1940 determinations were made with methanol as a solvent and the extraction was done with a Soxblet extractor. Table II gives the result.

TABLE II—Growth Hormone Content in the Ovaries of Flower Buds*

Tomato	Pepper	Cucumber Two Varieties	Big Tom Squash	Hubbard Squash	Crook-neck Squash	Buttercup Squash	Sugar Pie Pumpkin
16.34	10.93	5.19	2.03	.75 .36	1.2 .24	.16 .36	.19

*The figures denote indole acetic acid equivalents in Gammas per kg of fresh material.

It is obvious from the above data that the more compact ovaries of the tomato, pepper, and cucumber contain much more auxin than the more bulky and watery squashes, pumpkins, and watermelons. The tomatoes and peppers are quite easily induced to produce parthenocarpic fruits with chemical treatment, but so are crookneck summer and buttercup squashes. Yet the latter two have a rather low auxin content. Therefore, at the present it cannot be said that there is any relation between the auxin content in the ovary and the ease with which parthenocarpy can be induced. The writer believes that there is a positive correlation but only further experiments can prove or disprove this hypothesis.

There seems to be no doubt but that some chemicals are much more effective than are others and of the four presented here the most effective is naphthalene acetic acid. The indole butyric acid is also very good. The writer has previously (2) shown that indole butyric acid induces fruit development in the crookneck summer squash, but these fruits were not entirely normal in appearance. The indole acetic acid is not so good as the first two mentioned (1) and the 4-fluorene acetic acid has to be tested out further, but at the present indications are that it is less effective than the first two mentioned.

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Some Effects of Calcium and pH Upon Spinach[1]

By R. A. Schroeder, *University of Missouri, Columbia, Mo.*

IN THE production of spinach, considerable emphasis is placed upon the obtaining and maintenance of a proper soil reaction. It is popularly suggested that on most soils the optimum pH for its growth is between pH 6 to pH 7. At a reaction either markedly higher or lower it is believed that growth is retarded or stopped, and that plants are likely to be beset with various and sundry maladies.

It has been shown by other workers that plants may be subjected to a change in a number of several important soil factors other than a difference in the number of ionized hydrogen ions in the substrate, when they are grown at different pH levels. Before the cause of a result can be assigned to any one factor, it is necessary to determine the influence of all of the factors involved. Thus, it is important to know whether it is actually pH *per se* which is beneficial or detrimental as the case may be, or whether an associated factor or factors are causal. Albrecht (1), using a dialyzed hydrogen clay and working with soybeans, has separated the effects of hydrogen ion concentration from that of calcium, and shows that within the levels used, growth and nitrogen fixation increase with the calcium level, irrespective of the number of ions of hydrogen. In an attempt to determine the influence of various amounts of calcium on the growth and composition of spinach at different hydrogen ion concentrations, the following procedure was used:

Methods and Procedure

For a medium, the desired amounts of plant nutrients were added directly to clay taken from the "hardpan" of the Putnam silt loam subsoil. The clay was then mixed with definite amounts of white quartz sand to give a suitable physical texture. This Beidellite clay has an exchange capacity of roughly 28 milliequivalents per 100 grams of subsoil, 12 of which are hydrogen and 12 of which are calcium. The clay also has present upon it small quantities of potassium and phosphate, as well as small amounts of minor elements so that it is unnecessary to include them in the nutrients added.

The quantity of all the nutrients added except calcium was constant for all of the treatments. The amounts added per plant were: potassium, 6 M. E.; phosphate, 6 M. E.; magnesium, 3 M. E.; sulfate, 3 M. E.; and nitrogen, 10 M. E.

Calcium was supplied in varying amounts to give five different levels. The amounts added to the quantity originally on the subsoil were: 1, 0 M. E.; 2, 3 M. E.; 3, 6 M. E.; 4, 9 M. E.; and 5, 12 M. E. per plant.

In order to obtain the two desired pH levels, pH 5.2 and pH 6.8, different salts of the nutrients were used. For the pH 6.8 series, hydroxides were used as often as possible, and for the pH 5.2 series

[1]Contribution from the Department of Horticulture, Missouri Agricultural Experiment Station, Journal Series No. 718.

TABLE I—PERCENTAGE OF TOTAL EXCHANGE CAPACITY SATURATED WITH CALCIUM

0–5	3–5	6–5	9–5	12–5	0–7	3–7	6–7	9–7	12–7
42.8	53.5	60.0	64.2	67.3	42.8	50.0	55.1	58.9	61.9

the chloride, sulfate, and nitrate salts were added. This gave a final medium containing equal total quantities of nitrogen, phosphate, potassium, sulfate and magnesium in all calcium treatments and at both reactions. The percentage of the total exchange capacity of the clay which was saturated with calcium increased as calcium was added, and for the clay the calcium level was higher in the pH 5.2 series (Table I).

This resulted from the use of salts with different anions, which in turn necessitated differences in the amount of clay used. In total, there were five calcium levels at two pH's, giving 10 different treatments. Forty plants were grown in each treatment in individual pots. The variety used was Bloomsdale Long Standing.

CHEMICAL DETERMINATIONS

The samples were digested by the nitric and perchloric acid method. Material was analyzed by the spectrographic method, with the exception of phosphorus, for which the usual micro colorimetric method was used.

RESULTS AND DISCUSSION

The data (Table II) show that the addition of increasing amounts of calcium to the quantity of calcium on the original subsoil resulted in an increase in both the total fresh weight and dry weight of the spinach. Both the total fresh and dry weights of the pH 6.8 series were significantly greater than at pH 5.2 series. This held true for each of the calcium levels except in the series in which 9 M. E. were added

TABLE II—EFFECT OF FIVE CALCIUM LEVELS AT TWO REACTIONS UPON THE GROWTH AND COMPOSITION OF SPINACH*

Treatments	0–5	3–5	6–5	9–5	12–5	0–7	3–7	6–7	9–7	12–7
Total weight fresh (gms)	396.8	460.0	442.6	508.7	515.0	421.7	506.9	508.4	446.4	555.2
Total dry weight (gms)	44.1	52.7	49.3	55.9	57.1	47.8	59.9	55.9	51.8	63.7
Mgs Ca 10 gms dry weight	92.2	97.8	121.0	123.4	139.4	53.7	60.5	57.7	58.9	66.5
Mgs Ca total crop	406.3	515.2	596.7	690.3	795.5	256.9	362.5	322.5	305.2	424.0
Mgs P 10 gms dry weight	19.1	22.5	25.7	18.1	18.5	19.2	20.1	21.0	20.3	17.0
Mgs P total crop	84.1	118.6	126.8	101.1	105.6	92.0	120.4	117.5	105.0	108.6
Mgs K 10 gms dry weight	654.0	686.0	622.3	628.2	648.9	536.7	587.9	586.0	648.9	691.5
Mgs K total crop	2883.3	3615.3	3068.6	3513.4	3701.9	2568.1	3522.8	3275.5	3362.5	4408.3
Mgs Mg 10 gms dry weight	78.8	78.6	91.2	103.8	121.6	52.0	61.5	57.4	54.0	63.0
Mgs Mg total crop	347.4	414.0	449.7	580.8	693.7	249.0	368.7	320.8	279.8	401.5
Mgs Mn 10 gms dry weight	8.60	9.37	9.39	13.07	22.51	4.32	3.86	3.83	4.01	3.77
Mgs Mn total crop	37.9	49.4	46.32	73.09	128.42	20.68	23.1	21.4	20.8	24.0
Mgs Sr 10 gms dry weight	.44	.46	.53	.64	.77	.20	.23	.25	.25	.26
Mgs Sr total crop	19.32	24.5	25.9	35.8	44.00	9.6	13.6	14.2	12.7	16.7

*In treatments column, first figure refers to M. E. of calcium added per plant, second figure to pH of culture.

per plant. In this series, the weights were greater in the pH 5.2 levels.

Since the degree of calcium saturation of the media increased with each addition of calcium, the total fresh and dry weight became greater as the calcium saturation increased. It is impossible, however, from the data to allocate the relative importance of the degree of calcium saturation and total quantity of calcium.

It is of some significance that none of the treatments showed any visual symptoms of any deficiency except as a reduction in total vegetative growth. Therefore, apparently all plants were "healthy", and any differences cannot be ascribed to a chlorotic or otherwise "unhealthy" condition.

The analyses show that the calcium in 10 grams of dry weight increases as calcium was added. The increase was very significantly greater at a pH 5.2 than at a pH 6.8. The amounts of calcium in 10 grams was also much higher at the lower pH. At a pH of 6.8, when the calcium originally on the subsoil was augmented by 12 M. E., the amount of calcium in the plant was 66.516 milligrams per 10 grams, while at pH 5.2 it was 92.161 milligrams where no calcium had been added and where 12 M. E. had been supplied, there was a concentration of 139.443 milligrams.

The total milligrams of calcium in the crop increased as calcium additions were made. Here, too, the increases in the individual additions made as well as the total amount was greatest at pH 5.2.

The increase in total milligrams of calcium in the crop at pH 5.2 is practically a straight line function. Roughly, the total amount of calcium in the crop grown at pH 5.2 is 1.8 times as great as at pH 6.8, although the most vegetative growth was at the higher pH. The amount of calcium in 10 grams dry weight is 2.6 times greater at pH 5.2 where the amount of calcium available to the plant has been enlarged by 12 M. E., than when no calcium was added at pH 6.8. The total quantity of calcium in the crop was 3 times as great, using the same examples.

It is interesting to note that because of the calcium on the original subsoil and the larger quantities of clay used in the pH 6.8 series, the total amount of calcium present in the media was larger at the upper pH, and that still the total quantity of calcium in the crop was less.

The amount of phosphorus in 10 grams dry weight increased with calcium additions up to where 6 M. E. per plant were added, then the amount decreased. The amount where 12 M. E. of calcium were supplied is less than where no calcium was added. This held true at both pH levels. The peak of phosphate content at pH 5.2 was 22 per cent greater than the peak at pH 6.8. The maximum phosphate content per 10 grams was roughly 1.6 times greater than the lowest treatment. The total amount of phosphate in the crop for both pH's follows the same general pattern as does the quantity per 10 grams dry weight, in that it shows a maximum with increased calcium up to a point and then a decline. The decline, however, does not recede to a point so that the total amount of phosphate is below that of where no calcium is added to the cultures. Therefore, the increased calcium supplied results in a greater total absorption of phosphate in the crop.

The potassium content in 10 grams dry weight for the pH 6.8 series shows a rather consistent increase with increasing calcium, the highest calcium addition treatment being 28.9 per cent greater than when no calcium was added. The pH 5.2 series does not follow in the same general curve, as its greatest values at the lower calcium additions decline with additional calcium. However, the potassium content at the lower calcium levels of the pH 5.2 series is greater than at the corresponding calcium levels in the higher pH. Roughly, it is greater by 22 per cent at 0 M. E., 17 per cent at 3 M. E., and 6 per cent at 6 M. E.

The total amount of potassium in the crop shows for both pH series an increase as the calcium is increased. At the lower pH there was a 28 per cent increase as the calcium was added, and at the higher pH the increase was 72 per cent. The total potassium content of all the calcium treatments showed no significant differences between the plants grown at a pH 5.2 and those grown at a pH 6.8.

Magnesium determinations indicate that as the calcium increases the amount of magnesium in 10 grams dry weight also increases. The individual increase from one calcium level to the next highest level is greatest at pH 5.2. The increase from the 0 M. E. to the 12 M. E. series was 32 per cent at pH 5.2 and 20 per cent at pH 6.8. The amount of magnesium in 10 grams is considerably greater at the lower pH. The actual increase in amount in the pH 5.2 series over the amount in the higher pH is 0 M. E., 51 per cent; 3 M. E., 28 per cent; 6 M. E., 59 per cent; 9 M. E., 92 per cent, and 12 M. E., 95 per cent. The total quantity of magnesium in the crop also increased as calcium was added. The total amount is greatest in the pH 5.2 plants, and when all the calcium levels are totalled together the plants grown at a pH 5.2 showed a 54 per cent increase in the total amount of magnesium which they contained when compared with the plants grown at a pH 6.8.

The strontium determinations indicate that as calcium is added the strontium content per 10 grams dry weight also increases. There is an increase of 76 per cent in the pH 5.2 series, and an increase of 30 per cent in the pH 6.8 series, when the calcium level was raised from the 0 M. E. to the 12 M. E. treatment. The actual amount of strontium in 10 grams is greatest at the lower pH levels. In the treatment where 0 M. E. of calcium was added, there was a 67.7 per cent increase in strontium in the pH 5.2 series over the pH 6.8 series. At 3 M. E., the increase was 103.8 per cent; at 6 M. E., 106.8 per cent; at 9 M. E., 160.7 per cent; and at 12 M. E., 193.0 per cent.

The total content of strontium in the crop was increased at both pH levels as the calcium was increased. Including all calcium levels, the total amount in the crop was greater in the lower pH by 123.0 per cent than at the higher pH.

As the calcium was increased in the pH 5.2 level, the manganese per 10 grams of dry weight was increased. The manganese content where 12 M. E. of calcium was added was 2.6 times that where no calcium was added. In the pH 6.8 series, the manganese content per 10 grams was slightly depressed by the addition of calcium. The

maximum quantity per 10 grams in the pH 6.8 series was approximately half that of the lowest quantity absorbed in the pH 5.2 series. The total amount of manganese in the crop was definitely increased by calcium additions at the lower pH level, but only very slightly increased at the upper pH. In the pH 5.2 series, there was a 23.8 per cent increase in the amount of manganese absorbed by the spinach grown at the 12 M. E. of calcium level over the quantity taken in by the plants at the 0 M. E. of calcium level.

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The Effect of Culture Solution Temperature on Water Intake and Wilting of the Muskmelon[1]

By G. J. RALEIGH, *Cornell University, Ithaca, N. Y.*

WHILE conducting experiments with muskmelons plants in culture solutions, it was noted that the plants wilted severely during the morning on two bright August days following low night temperatures. Early in the morning of the second day that wilting occurred the solution averaged 53 degrees F. Due to the high specific heat of water they remained at relatively low temperatures for a considerable period after greenhouse temperatures had risen, which suggested that the low solution temperatures reduced water intake at a time when transpiration was high. Several cases of wilted muskmelon plants in moist soils were reported as occurring during warm morning following low night temperatures. It seemed desirable to compare the behavior of uniform plants grown in solution maintained at 50 degrees F with others at 65 and at 80 degrees F under conditions conducive to high transpiration.

Schroeder (1) found low soil or culture solution temperatures caused water deficiencies in cucumbers and concluded that 70 degrees F or slightly higher was the most practical soil temperature for the crop.

Two experiments were conducted, the first with older plants in stoneware jars with special stoneware tops; the second with younger plants in Pyrex beakers. The results were similar but because the plants used for the second experiment were more uniform, and since the Pyrex containers were more suitable for the work than the stoneware crocks the data from the latter experiment only are reported.

Seed of the Delicious variety of muskmelon was sown in quartz sand on August 23. On September 11 the seedlings were transferred to stoneware jars containing culture solutions of the following concentration: KH_2PO_4, 0.0005M; $MgSO_4$, 0.001 M; $Ca(NO_3)_2$, 0.0025M; KNO_3, 0.0025M; and B 0.5 parts per million, Mn 0.5 parts per million, Zn 0.05 parts per million, Mo 0.05 parts per million, and Cu 0.02 parts per million.

On September 27 plants were transferred to solutions one-half as concentrated in 2-liter Pyrex beakers. Squares of thick Pyrex plate glass were used as tops for the beakers. Each top was equipped with suitable openings for three plants and a sintered Pyrex glass aerator. Lots of three plants each were weighed after allowing most of the water to drip from them and placed in beakers containing 2,000 cubic centimeters of solution.

The beakers were set into 15 liter flat iron tanks filled with sufficient water to bring the water surrounding the beakers three-quarters of the way to the top of the beakers. Ice or warm water was added to each tank as required to maintain solution temperatures of 50 degrees F, 65 degrees F, and 80 degrees F. Heavy black paper was placed over the tank around each beaker to shield the solution from light and to make for greater uniformity of air temperature around the stems and

[1]Paper No. 231, Department of Vegetable Crops, Cornell University, Ithaca, New York.

leaves of the plants in the various solutions. All treatments were run in triplicate. Temperatures as indicated by a standardized thermometer in each beaker did not vary more than 2 degrees F in any treatment and never more than ½ degree for any extended period. Solution temperatures were maintained from 9 a.m. on September 27 to 5 p.m. after which time all solutions were allowed to come to equilibrium with greenhouse temperatures. On September 28 the experimental temperatures were maintained in these solutions from 8 a.m. to noon. Both days were cloudless. The average light readings in the greenhouse at 2 p.m. on September 27 were 9,150 and at 11:30 a.m. on September 28, 9,450 foot candles. During the period that the solutions were kept at experimental temperatures the greenhouse temperature was kept at approximately 90 degrees F.

On the first day the plants in the solution kept at 50 degrees F began to wilt 20 minutes after the solutions were lowered to 50 degrees F and the plants remained flaccid throughout the day. Some of the leaves of the plants in the 65 degrees F solutions drooped slightly. Thermocouple readings from the wilted leaves of plants in solutions at 50 degrees F averaged about 10 degrees F higher than those from the turgid leaves of plants in solutions maintained at 80 degrees F. The lower leaves on the plants in solutions at 50 degrees F became sufficiently dry before 5 p.m. that they did not recover during the night as did the other leaves of these plants.

At noon on September 28, plants were removed from the solution after allowing it to drip from the roots as had been done when the plants were placed in the beakers and the volume of solutions measured.

The initial wet weight of the plants and the total amount of solution removed from each beaker are shown in Table I.

TABLE I—Effect of Culture Solution Temperature on Water Intake by Muskmelon Plants

Temperature of Solution (Degrees F)	Weight of 3 Plants at Beginning of Experiment (Gms)	Total Amount of Solution Used During Course of Experiment (1⅙ Days) (Mls)
50	34.6	52
	23.8	38
	27.5	51
	Average 28.6	47
65	32.9	160
	30.8	167
	32.6	153
	Average 32.1	160
80	39.8	302
	30.9	227
	33.6	241
	Average 34.8	285

These data indicate that water intake from culture solutions by muskmelon plants in air temperatures of about 90 degrees F is very low from solutions kept at 50 degrees F and is markedly reduced at 65 degrees F as compared with 80 degrees F.

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Nutrient or Starter Solutions and Vitamin B for Transplanting Tomatoes

By CHARLES B. SAYRE, *N. Y. Experiment Station, Geneva, N. Y.*[1]

THIS is a report of a development of work previously reported (1, 2) in which the treatments which previously gave the best results were continued and compared with some new combinations, some of which contained Vitamin B complex. In these experiments comparing different formulae each solution was poured around the roots of tomato plants at the time they were transplanted to the field, similar to the manner water would be ejected around the roots when using a transplanting machine. In another series of field test a "starter" solution was compared with plain water in a transplanting machine. In a third series, the starter solution was poured on tomato seeds at the time they were planted in the field.

In all of these experiments the Nystate variety of tomatoes was used. For the transplanted series the seed was sown April 1, in flats in the greenhouse and the seedlings pricked off when about 2 inches tall and set 108 plants to a flat measuring 16 by 22 inches similar to those used in commercial production of cannery tomatoes. The flats were later transferred to coldframes and the plants moderately hardened. In the series comparing different kinds of transplanting solutions the plants were transplanted to the field on May 29. The plants were set 3 feet apart in rows 5 feet apart. This spacing requires 2,904 plants per acre and at ¼ pint of solution per plant would require 91 gallons of solution per acre, which approximates the amount commonly used in commercial practices. The field was fertilized with 600 pounds per acre of 5–20–5 fertilizer drilled across the entire area before the plants were transplanted. Consequently this experiment was a direct comparison of 10 different solutions versus plain water in transplanting tomatoes to a well fertilized field. The 11 treatments were replicated in randomized arrangement four times in adjacent blocks. There were 20 plants per row in each treatment. The soil is Ontario loam, naturally calcareous, and had a pH of 7.2.

The yields of marketable tomatoes are presented in Table I. To show the effect of the starter solutions on earliness of maturity as well as on total yields, the yield records have been divided into periods, showing the early yields, that is to August 31; the mid-season yields, that is from September 1 to 10, and the late yields, that is from September 11 to 27; and the three increments combined in the total yields. In each period the actual yield and also the gain or loss for each treatment is given as compared with the check treatment. The check treatment received the same field fertilization as the other treatments and plain water at transplanting time. In Table I the treatments are arranged in the order of their total yields.

Examining the yield records by periods (Table I) it is evident that only five of the treatments (Nos. 1, 2, 3, 7 and 8) all of which con-

[1]Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 422.

TABLE I—EFFECT OF VITAMIN B AND VARIOUS STARTER SOLUTIONS ON EARLINESS AND TOTAL YIELD OF TOMATOES (1940)

Treatment No.	Ingredients per 50 Gallons of Water ¼ Pint Per Plant	To Aug 31		Sep 1 to Sep 10		Sep 11 to Sep 27		Total Yields	
		Tons Per Acre	Gain or Loss	Tons Per Acre	Gain or Loss	Tons Per Acre	Gain or Loss	Tons Per Acre	Gain or Loss
1	2 pounds 10½ ounces Ammo Phos A, 1 pound 5½ ounces KNO_3 (4 pounds 11–32–14 transplanting mixture)	1.00	.49	2.79	1.79	8.12	.75	11.91	3.03
2	2½ pounds Di-ammonium phosphate, 2½ pounds mono-potassium phosphate (5 pounds "Takehold" mixture 12–52–17)	.97	.46	2.94	1.94	7.63	.26	11.54	2.66
3	5 pounds 5 ounces Ammo Phos A (11–48–0)	1.04	.53	2.43	1.43	7.86	.49	11.33	2.45
4	5 pounds Mono-potassium phosphate (0–52–35)	.73	.22	1.39	.39	9.06	1.69	11.18	2.30
5	2 pounds 11 ounces KNO_3 (13–0–44)	.78	.27	1.30	.30	8.96	1.59	11.04	2.16
6	50 fluid ounces liquid phosphoric acid (75 per cent)	.73	.22	1.50	.50	8.66	1.29	10.89	2.01
7	5 pounds 5 ounces Ammo Phos, 2 pounds 11 ounces KNO_3, 1 fluid ounce Vita-Flor. (8 pounds 11–32–14 mixture + 1 ounce Vitamin B complex)	1.05	.54	2.74	1.74	6.97	−.40	10.76	1.88
8	5 pounds 5 ounces Ammo Phos, 2 pounds 11 ounces KNO_3 (8 pounds 11–32–14 mixture	1.03	.52	2.36	1.36	7.35	−.02	10.74	1.86
9	12 gallons manure water + 50 fluid ounces phosphoric acid	.67	.16	1.38	.38	8.55	1.18	10.60	1.72
10	1 fluid ounce Vita-Flor (Vitamin B complex)	.66	.15	2.0	1.00	6.92	−.45	9.58	.70
11	Water only (Check)	.51	—	1.0	—	7.37	—	8.88	—
	Difference necessary for significance 19 to 1	—	.31	—	.64	—	1.55	—	1.71

Entire field fertilized with 600 pounds of 5–20–5 per acre drilled before setting plants. "Starter" solutions applied at rate of ¼ pint per plant except number 1 which received ½ pint. Only marketable fruit included in these records.

tained either mono-ammonium or di-ammonium phosphate produced significant gains in early yields and also in mid-season yields as compared with the check. None of these treatments produced significant gains in late yields (after September 10) but the large earlier yields resulted in significant gains in the total yields. There was no significant difference between these treatments. It appears, therefore, that nitrogen and phosphorus are particularly important ingredients of a starter solution in stimulating earliness of tomatoes.

The largest total yield was produced by treatment No. 1 which consisted of 4 pounds of the mixture of two parts Ammo Phos and one part nitrate of potash dissolved in 50 gallons of water. This solution was used at the rate of ½ pint per plant. All of the other treatments were used at the rate of ¼ pint per plant. This treatment produced an increase of .49 tons per acre in early yield, 1.79 tons in mid-season yield, and .75 tons in late yield. The total yield was 3.03 tons greater than the check. The ingredients for this treatment known as the 11–32–14 transplanting mixture retailed in Geneva at 55 cents for 10 pounds or $4.00 per 100 pounds. At the 10 pound price the 14½ pounds of materials for this treatment cost only 80 cents per acre.

Therefore, the gain of 3.03 tons from this treatment was very profitable.

This same mixture was used at double the concentration (8 pounds per 50 gallons) in treatment No. 8 but using only half as much solution (1/4 pint) per plant. Consequently the total amount of material used was the same in each treatment except that more water was used in No. 1. Treatment No. 8 produced an increase in early yield of .52 tons, a mid-season gain of 1.36 tons, no gain in late yield, and a total gain of 1.86 tons, which was also a very profitable treatment.

The second largest total yield was produced by treatment No. 2 which was composed of 5 pounds of a mixture of di-ammonium phosphate and mono-potassium phosphate in 50 gallons of water. This treatment produced a gain of .46 tons in early yield, the largest mid-season yield with a gain of 1.94 tons more than the check, a slight gain (.26 ton) in late yield and a total gain of 2.66 tons more than the check treatment.

The third largest yield was produced by treatment No. 3, which consisted only of 5 pounds 5 ounces of Ammo Phos A per 50 gallons. This is the same amount of Ammo Phos as used in treatments Nos. 7 and 8. Previous greenhouse tests had indicated that phosphorus was the ingredient in the "starter" solution that was most effective in stimulating growth of plants though the tests also indicated that a physiologically balanced mixture of nitrogen, phosphorus, and potash was better than phosphorus alone. In this test, treatment No. 3, which contained the same amount of phosphorus and two-thirds as much nitrogen and no potash, gave as good results as treatments 1, 2, 7 and 8. However, this experiment was on an alkaline well-buffered soil. Some greenhouse tests on acid, poorly buffered soils showed a marked advantage in having some nitrate of potash with the Ammo Phos. In this field experiment, however, the Ammo Phos alone produced significant gains in early and mid-season yields, a slight but not significant gain in late yields and a significant gain of 2.45 tons in total yields, which made it a very profitable treatment.

The only other treatment to produce significant gains in early, mid-season, and total yields was No. 7, which was the same as No. 8 plus 1 fluid ounce of Vita-Flor (Vitamin B complex) per 50 gallons of water. This treatment produced a gain of .54 ton in early yield, 1.74 tons in mid-season gain, but produced .4 ton less than the check in the late yield. The total gain from this treatment was 1.88 tons. The yields from treatments No. 7 and No. 8 were practically equal and the only difference between the treatments was that No. 7 contained Vitamin B complex. It is evident, therefore, that the vitamin was of no value in the transplanting solution.

None of the five treatments that produced significant gains in the early and mid-season yields were significantly better than the check in late yields (after September 11) though their total yields were all significantly better than the check. There were two treatments (Nos. 4, 5), however, which produced significantly larger late yields than the check, and these late gains combined with small earlier gains produced significantly larger total yields than the check. These treatments show some interesting comparisons that merit consideration.

Treatment No. 4 which consisted only of 5 pounds of mono-potassium phosphate per 50 gallons produced the largest late yield (1.69 tons more than the check) and small but not significant gains in early and mid-season yields, but a substantial gain (2.3 tons) in total yield. This treatment contained the same amount of phosphorus and twice as much potash as treatment No. 2, but no nitrogen. Since treatment No. 3 which contained nitrogen and phosphorus but no potash produced significantly larger early and mid-season yields than No. 4 or No. 5, it appears, that in the transplanting solution, nitrogen with phosphorus is more important than potash with phosphorus in increasing earlier maturity of tomatoes. It is interesting to note that in the 1939 experiments (2) the mono-potassium phosphate also produced a significant gain in the late crop.

Another treatment that produced a large late yield was No. 5, which consisted only of 2 pounds 11 ounces of nitrate of potash. This is the same amount of nitrate of potash as used in treatments No. 7 and No. 8 and should be compared with these treatments and with treatment No. 3 to show the relative importance of the Ammo-Phos and of the nitrate of potash in the special mixture of two parts Ammo Phos and one part nitrate of potash used in treatments 1, 7 and 8. Comparing these various treatments it is evident that the phosphorus with nitrogen was more important than phosphorus with potash or nitrogen with potash in increasing early yields, and that a balanced ratio of nitrogen, phosphorus, and potash was better than a mixture lacking any one of these elements.

Treatment No. 6 which consisted of 1 liquid ounce of phosphoric acid (75 per cent) per gallon of water produced a large late yield which resulted in a significant gain in total yield though the early gains were trifling. From the appearance of the plants and roots shortly after transplanting it was found that this solution was too acid and injured the roots though the plants subsequently recovered. This probably accounts also for the poor showing made by treatment No. 9, which contained the same amount of phosphoric acid plus manure water. The author had expected this to be a superior treatment because the manure water contains growth promoting substances and minor elements and nitrogen and potash. It was to boost the low phosphorus content that the phosphoric acid was added, but it is known now that the acidity proved injurious to the roots. A less acid form of phosphorus would have been better.

Treatment No. 10 consisting only of 1 fluid ounce of Vita-Flor (Vitamin B complex) per 50 gallons of water was the only treatment that failed to produce a significant gain in either early, late, or total yields. This and the results obtained with treatment No. 7 support other experiments at Geneva and at many other stations showing that the addition of Vitamin B is of doubtful value in crop production in an agricultural soil.

Another experiment was designed to show that a starter solution is not adequate as the sole fertilizer treatment; but is, as the name implies, merely a readily available fertilizer applied at a critical time in the life of the plant so as to give the plant a quicker start and thus

stimulate earlier growth and larger yields. A very small amount of plant food is all that a small seedling or plant requires and if this small amount is correctly applied when most needed it will produce extraordinary returns.

In this experiment the plats were 1/40th of an acre and were three rows wide. Each treatment was replicated three times. The plants were set with a Holland transplanting machine adjusted to eject ¼ pint of water around the roots as each plant was set. In this experiment the starter solution was a mixture of two parts Ammo Phos 11–48 and one part nitrate of potash 13–0–44 used at the rate of 8 pounds of the mixture per 50 gallons of water, the same as in treatment No. 8, Table I. A green manure crop of 2-year-old sweet clover was plowed under for this tomato crop and probably accounts for the large yields of the unfertilized plots. Table II gives the average yields of marketable fruit from the three replications of each treatment.

TABLE II—Effect of "Starter" Solution and Drilled Fertilizer on Yield of Tomatoes (1940)

No.	Treatment	Early Yield		Total Yield	
		Tons Per Acre	Gain Over Check	Tons Per Acre	Gain Over Check
12	No fertilizer (check)	.76	—	8.38	—
13	Starter solution only	1.66	.90	9.31	.93
14	Starter solution + 600 pounds 5–20–5 drilled	2.64	1.88	12.30	3.92
	Difference necessary for significance (19 to 1)	—	.72	—	1.60

These plats showed some interesting differences as the season progressed. Within 2 weeks after transplanting the lots receiving starter solution (Nos. 13 and 14, Table II) had become established and were growing rapidly and were considerably larger than the check plats (No. 12). There was no apparent difference in the rate of growth of the lots which received starter solution only (No. 13) and the lot receiving starter solution plus field fertilizer (No. 14) until about 5 weeks after transplanting. At that time plants in both these lots were distinctly larger than those in the lot receiving no fertilizer. But from then on the lot that received field ferilizer (No. 14) grew considerably larger than the one receiving starter solution only (No. 13), which maintained its advantage over the unfertilized lot (No. 12). It was evident that the "starter" solution stimulated earlier growth but that as the plants grew additional fertilizer was needed to produce a large crop.

The stimulating effect of the "starter" solution is shown in Table II. The "starter" solution alone produced 1.66 tons of early tomatoes or more than double the .76 ton produced with no fertilizer. This gain of .9 ton in early yield was substantially the same as the .93 ton gain in total yield due to the "starter" solution alone. However, in the areas where 600 pounds of 5–20–5 fertilizer was applied deeply with a fertilizer drill before the plants were set and then "starter" solution used in the transplanting machine (No. 14, Table II) the early yield was 2.64 tons per acre or 1.88 tons more than the check. This is more than

double the gain produced by the "starter" solution alone. The total yield from the fertilizer plus "starter" solution was 12.3 tons, a gain of 3.92 tons over the check and more than four times the gain from the starter solution alone.

In a third experiment the same "starter" solution (8 pounds of 11–32–14 per 50 gallons) was poured on tomato seed sown directly in the field. Direct seeded tomatoes are not transplanted and therefore develop a tap root and more deeply penetrating root system. However, they cannot be sown in the field until danger of frost is past. The short frost-free period at Geneva makes a very short growing season. Consequently the "starter" solution was tried on some direct seeded tomatoes to see if it would hasten their development.

This experiment was adjacent to that reported in Table I and received the same fertilizer treatment, that is 600 pounds of 5–20–5 commercial fertilizer drilled deeply across the entire field, 2 days before the seed was sown. The field was marked off in rows 5 feet apart and cross marked 3 feet apart. At each cross mark about 10 tomato seeds were dropped and ¼ pint of "starter" solution poured on the seed (treatment No. 15, Table III), and ¼ pint of plain water in the check treatment (No. 16). The seed was then covered by scraping a little soil over it with the foot. This seed was sown May 8. Each treatment was replicated five times with 20 "hills" per row. When the seedlings were about 3 inches high they were thinned to one plant per hill and there was a full stand on all rows. The yield records are given in Table III.

TABLE III—Effect of "Starter" Solution on Field Seeded Tomatoes

No.	Treatment	Early Yield		Total Yield	
		Tons Per Acre	Gain Over Check	Tons Per Acre	Gain Over Check
15	¼ pint "starter" solution	.77	.63	8.49	1.15
16	¼ pint water (check)	.14	—	7.35	—
	Difference necessary for significance (19 to 1)	—	.29	—	1.32

As these seedlings emerged the stimulating effect of the "starter" solution soon became apparent. The seedlings in all replications that received the "starter" solution grew much more rapidly and as shown in Table III they produced a significantly earlier crop, .63 ton gain; and a larger total yield, 1.15 tons gain, a very profitable increase from 80 cents worth of fertilizer.

Conclusions

A small amount of readily available fertilizer in solution poured around tomato roots when transplanted to the field or on the seed when seeded directly in the field proved very effective in stimulating earlier growth and increasing yields under the conditions of these experiments. Mono-ammonium phosphate (Ammo Phos 11–48) alone or in combination with nitrate of potash (13–0–44), and also a mixture of di-ammonium phosphate and mono-potassium phosphate proved the

most satisfactory of the 10 combinations tried in this experiment. One-fourth pint of very dilute solution per plant was sufficient. Vitamin B complex as used in this test proved of no value. Materials for a good "starter" solution cost only about 80 cents per acre and can be mixed in the water in the transplanting machine. The "starter" solution was not adequate as the sole fertilizer, but was most effective when used as a supplement to the regular field fertilization.

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The Effect of Fruit Rot of Eggplant on Seed Germination

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In a study of varietal differences in the germination of seed of eggplant, preliminary tests indicated that the presence of fruit rot caused by the fungus *Phomopsis vexans* was associated with poor seed germination without obvious evidence of diseased seedlings. Harter (2), Edgerton (1), and others have recognized that this fungus may cause seedling blight as well as fruit rot. Edgerton has shown that fungus mycelium may be found in apparently sound seeds. This study was made to determine the relation of fruit infection to seed germination without any attempt to determine seed infection.

On October 7, 1940, fruits were collected at Beltsville, Maryland, from the two varieties Black Beauty and Fort Myers Market, from plants raised in the Vegetable Variety Standardization project. The fruits of each variety were divided into four groups: no infection, slight infection with one to two lesions per fruit, medium infection with several lesions per fruit, and severe infection with 80 to 100 per cent of the fruit surface covered with lesions (Fig. 1). There were six to nine fruits in each group. After extraction, the lightest "seed" was floated off in water. After drying overnight at room temperature, the material was cleaned with a vertical air blast in an attempt to separate

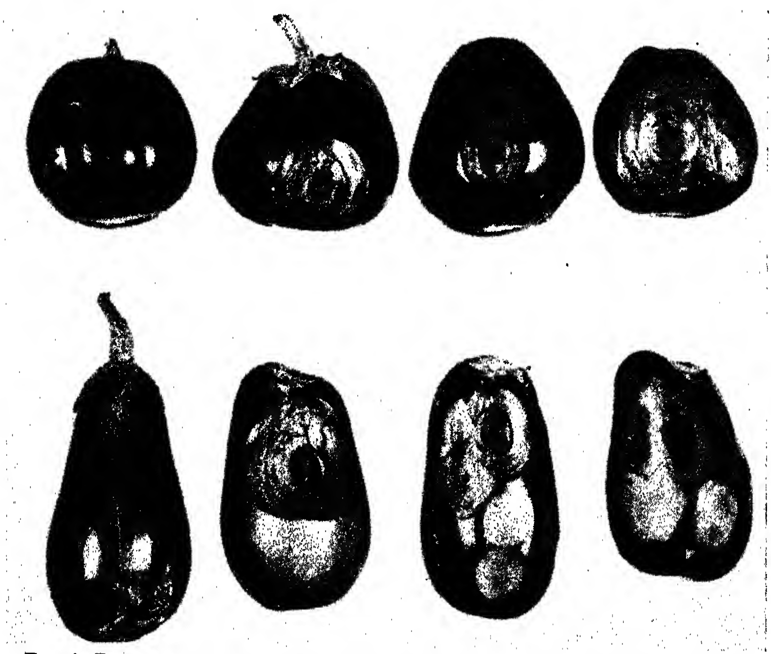

Fig. 1. Degree of infection of four groups of eggplant fruits. Above, Black Beauty; below, Ft. Myers Market.

TABLE I—Progress of Germination at 20 to 30 Degrees C Temperature Alternation of Eggplant Seed From Healthy and Diseased Fruits

Days in Germination	Percentage of Germination of Seed from Fruits Infected as Shown			
	None (Per Cent)	Slight (Per Cent)	Medium (Per Cent)	Heavy (Per Cent)
		Black Beauty		
5	92.50	43.25	35.00	34.50
6	97.25	68.50	47.25	54.75
7	98.00	79.50	54.25	62.00
10	98.50	90.25	64.25	67.50
11	98.50	90.25	64.25	68.25
14	98.50	90.50	72.25	71.00
21	—	90.50	74.00	71.25
		Ft. Myers Market		
5	75.50	27.50	24.00	39.75
6	91.00	41.75	33.25	57.50
7	99.00	50.50	43.00	63.00
10	99.25	61.50	72.75	73.50
11	—	61.50	75.00	73.75
14	—	63.00	82.50	75.75
21	—	63.00	84.25	76.25

the empty coats and light, poorly developed "seeds" from the heavy well developed seeds. Germination tests were started October 12 using only the heavy seeds. The seed was placed between moist blotting paper in quadruplicates of 100 and kept at 30 degrees C for 7 hours, and at 20 degrees for 17 hours each day.

The results of the germination tests are shown in Table I. The seeds from the healthy fruits germinated at a much faster rate and had a much higher final percentage of germination than the seeds from the diseased fruits. Seeds from the three classified groups of diseased fruits showed no consistent differences in their germination behavior.

The slight irregular differences in moisture content of the seeds from the different groups would not explain the differences in germination (Table II). The bulk of seed extracted from healthy fruits had a very large proportion of heavy seeds with a plump hard surface, but the bulk of seed from the three groups of diseased fruits had an appreciably

TABLE II—Some Characteristics of the Seed Recovered From Healthy and From Diseased Fruits of Eggplant

Degree of Fruit Infection	Approximate Per Cent of "Heavy" Seed in Bulk	Moisture Content (Per Cent)*	Weight of 1000 "Heavy" Seeds (Dry Weight Basis—Grams)	Relative Weight of Seeds Compared to Healthy as 1
		Black Beauty		
None	99	9.55	4.564	1
Slight	90	8.93	4.046	0.89
Medium	89	8.84	3.605	0.79
Heavy	85	8.68	3.999	0.88
		Ft. Myers Market		
None	99	9.13	3.955	1
Slight	50	8.87	3.869	0.98
Medium	78	9.15	3.747	0.95
Heavy	92	8.77	3.767	0.96

*Day on which germination tests were started.

lower, and in some cases, much lower proportion of heavy seeds; and many of these, although hard, were shrunken and discolored. With Black Beauty, the heavy seeds from the diseased fruits were lighter in weight than from healthy fruits. It would appear that the presence of the rot in the fruit results in poor development of the seed and in retarded and lower germination.

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Further Studies of Electricity in Sweetpotato Plant Production

By J. B. Edmond and G. H. Dunkelberg, *Clemson Agricultural College, Clemson, S. C.*

Abstract

The complete paper will be published as a bulletin of the *South Carolina Agricultural Experiment Station.*

INVESTIGATIONS were initiated at Clemson College in the spring of 1939 to determine the influence of certain environmental and cultural factors on sweetpotato plant production in electrically heated hotbeds. The most important results are published in the Fifty-second Annual Report of the South Carolina Agricultural Experiment Station (1). The investigations were continued in the spring of 1940. Tests were made with various types of hotbed covers, narrow and moderately wide horizontal spacing of the heating cable, different soil temperatures, various types of bedding media and "regular" and "crowded" bedding of the roots.

The covers tested were muslin, Sunray cloth, Sunray glass and Cal-Nitro sacks. The results show that Sunray glass and Cal-Nitro sacks produced a greater number of plants per root and per bushel than muslin and Sunray cloth. On the other hand, the Sunray cloth consumed less electricity than Cal-Nitro sacks, Sunray glass and muslin. Since muslin produced the lesser number of plants per root and per bushel and used a larger quantity of electricity, it was the least satisfactory type of cover used in the experiment. Further tests are necessary on the other type of covers before definite recommendations can be made.

The heating cable was placed 7, 10 and 13 inches apart. The data show that the influence of the 10-inch spacing is particularly striking. It produced considerably more plants per root and per bushel than the 13-inch spacing and used considerably lesser quantities of electricity per unit area of bedding space than the 7-inch spacing. This greater plant production and lesser electrical consumption combined to produce more plants per unit of electricity than the 7-inch and the 13-inch spacings. In other words, the data show that the 10-inch spacing is more economical than the 7-inch and 13-inch spacings. Accordingly, spacing of the cable approximately 10 inches is recommended.

Soil temperatures compared were 73 to 75 degrees F, 78 to 80 degrees F, 83 to 85 degrees F and 88 to 90 degrees F. Plant production and electrical consumption varied with the hotbed soil temperature. In general, the higher the soil temperature the greater was the number of plants per root and per bushel and the greater was the quantity of electricity used per unit area of bedding space. However, the highest temperature did not produce the most profitable returns. On the basis of a price of $1.75 per thousand plants for the entire plant production period and a cost of 2 cents per kilowatt-hour for the electricity, the 83 to 85 degrees F bed produced the highest net returns followed by

the 78 to 80 degrees F bed, the 88 to 90 degrees F bed and the 73 to 75 degrees F bed in the order named. For the commercial plant grower, at least, the maintenance of a temperature from 80 to 85 degrees F is recommended.

Bedding media compared were soil, sand and sawdust. The data show that the bedding media markedly influenced plant production and electrical consumption. The soil, as a bedding medium, produced by far the greater number of plants per root and per bushel and used a somewhat greater quantity of electricity per unit area of bedding space than sand or sawdust. As a result of the greater plant production of the roots bedded in soil, the number of kilowatt-hours required to produce 1,000 plants was significantly lesser than that for the other media. Although these results indicate that soil as a bedding medium is superior to the other media tested, additional experiments with these materials will be made in 1941.

"Crowded" bedding consisted of placing 300 roots in 18 square feet of bedding space and "regular" bedding consisted of placing 150 roots in an equal area. The results show that "crowded" bedding markedly increased the number of plants produced per unit area of bedding space and only slightly increased the amount of electricity necessary to maintain the proper temperature. This greater plant production combined with the slightly greater electrical consumption markedly decreased the amount of electricity required to produce unit number of plants. Furthermore, "crowded" bedding failed to increase rotting in the bedded stock. These results are similar to those obtained in 1939 and indicate that this method of bedding is worthy of trial, particularly for the grower who practices sanitation in plant production operations.

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Some Responses of Tomato Fruits to Methyl-Bromide Fumigation

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TOMATOES moving from California into the Northwest are fumigated with methyl-bromide for the control of the tomato pinworm. The packed lugs are placed in cars, drains and leaks plugged with wet papers, and methyl-bromide introduced into the car at the rate of 2 pounds per 1,000 cubic feet of car space. After 2 hours of exposure to the gas the cars are aired with fans for 1 hour. Little gas is supposed to remain in the car after a half hour of airing except that which has been absorbed by the fruit.

The cars are shipped under standard ventilation. During periods of high temperature the handling and shipping procedure may result in fruit temperatures averaging well above 80 degrees F from the time of harvest until the fruit reaches its destination.

The poor market quality of the fruit noted in some gassed shipments on arrival at destination raises the question whether the CH_3Br may have an influence on the fruit. The results of certain preliminary studies are reported here.

Experimental Methods

"Mature-green" fruits, and in some experiments "pink" fruits were placed in 5-gallon glass containers in a room the temperature of which ranged between 70 and 90 degrees with an average of 80 degrees F. These containers were sealed and gassed with CH_3Br at various concentrations for different lengths of time ranging from less to somewhat more than the commercial treatment. The control jars were sealed without gassing for 4 hours and then ventilated. Following treatment the seals were removed, and the jars aired for 24 hours in order to remove as completely as possible all CH_3Br from the fruits. Then the fruits were placed in respiration chambers or in storage rooms. Periodic observations were made of the rate of ripening of the various lots. When the fruits were ripe duplicate samples of juice for each lot were obtained by grinding and filtering composites consisting of quarters of each of the fruits. The pH of the juice was determined with a quinhydrone electrode, the soluble solids by means of a Zeiss hand refractometer and the total acidity by titration of a 1–10 dilution with distilled water using phenoththalien or cresol red as an indicator. Samples of the fruits comparable to those used in other tests were tasted by a group to determine if the edible quality had been affected.

Fruits used in respiration were allowed to ventilate one day after fumigation prior to setting up in the respiration chambers except in the case of one series of pinks, where respiration tests were begun as soon after fumigation as was feasible. All respiration tests were made in a constant temperature room set at 68 degrees F.

The method used in determining the respiration rate was by means of collecting in an alkali solution the CO_2 emanating from the fruit.

Compressed air was bubbled through two jars containing NaOH to remove the CO_2 present, and then on through jars containing the fruits under study, after passing through flowmeters regulated to a uniform volume. After passing over the fruit the air was bubbled through a sintered glass bubbler into an absorption tower containing NaOH. One cubic centimeter of butyl alcohol was used in each tower to increase surface tension and reduce the size of bubbles.

The amount of CO_2 was determined by making the $NaOH$–Na_2CO_3 solution up to volume and titrating an aliquot with .1N HCl after adding an excess of $BaCl_2$. A double indicator of Thymol Blue and Cresol Red was used, titrating through the blue but not the pink to a pH of about 7.6.

Treatments and Results

Ripening:—Fruits of the variety Pearson were harvested September 9, gassed, aired and on the following day placed under different temperature conditions. Beside the two control lots, the treatments comprised 1 pound of CH_3Br per 1,000 cubic feet for 2, 4, and 8 hours, 2 pounds for 1, 2, 4 or 8 hours and 4 pounds for 1, 2, or 4 hours. Part of the fruits were used for respiration studies at 68 degrees F (relative humidity above 90 per cent), others were held at an average temperature of 80 degrees F (relative humidity 35 per cent) while the remainder were placed at 50 degrees F (relative humidity 80 per cent) for 10 days and then moved September 20 to a ripening room the temperature of which was maintained at 68 degrees F (relative humidity 90 per cent). The fruits which were gassed at the 4 pound rate were all injured and spoiled quickly without ripening regardless of the subsequent temperature. The fruits treated with 2 pounds of gas for 4 or 8 hours also broke down without ripening in the 50 degrees F storage.

After 11 days at 80 degrees F there were fewer ripe fruits in the controls than in the treated lots. The fruits held at 68 degrees F showed after 10 days a somewhat greater number of ripe fruits in the controls than in the gassed lots. The tomatoes which had been held previously for 10 days at 50 degrees F showed after 7 days at 68 degrees F a larger percentage of ripe fruits in the controls than in those treated.

On September 18, fruits of the variety 133–6 were harvested, gassed, aired and on the next day placed under temperatures similar to those described above. The treatments consisted of 1 pound of methylbromide for 4 hours, 2 pounds for 1 hour and 2 pounds for 2 hours. After 12 days at 80 degrees F there were as before fewer ripe fruits in the controls than in those treated with CH_3Br. At the end of 8 days at 68 degrees F there was little difference between the controls and those receiving 1 pound of the bromide for 4 hours, but the ripening of the fruit gassed with 2 pounds was delayed. When the fruits were held for 10 days at 50 degrees F and then for 12 days at 68 degrees F the ripening of the controls was considerably ahead of that of the gassed fruits.

Fruits of the variety, 133–6 were harvested September 23, gassed, aired for 24 hours and then placed at the various temperatures used

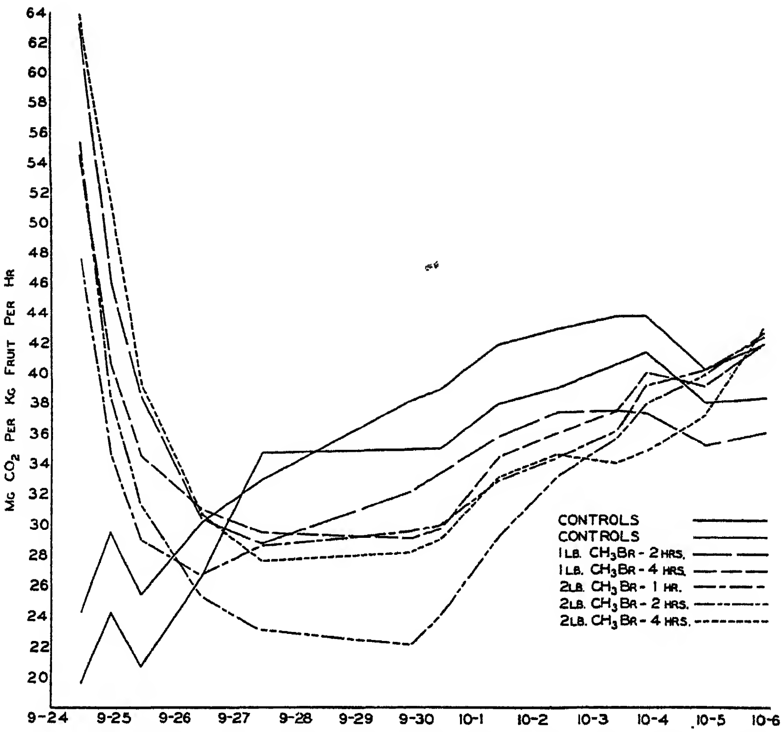

FIG. 1. The respiration curves obtained with "mature green" 133–6 tomatoes harvested September 23. The respiration determinations commenced after a 24-hour ventilation period.

above. The data on this lot are presented in Table I. In this series also the ripening of the controls at 80 degrees F was slower than for the tomatoes treated with CH_3Br. The ripening of the 2 pound for 4 hours treatment held at 68 degrees F for 15 days appears to be abnormal as was also the respiration curve for this particular lot (Fig. 1). After 10 days storage at 50 degrees F the controls subsequently ripened more rapidly than the gassed tomatoes.

It would appear from the data in Table I that the ripening of the controls was somewhat slower at 80 degrees F than at 68 degrees F, although the lower relative humidity at the higher temperature may have been a factor. However in the series of September 9 and 18 this delay of ripening at 80 degrees also occurred. Rosa (2) and Wright and Gorman (3) have pointed out that at 80 degrees F and above the coloring of tomato fruits is affected.

A series with mature green tomatoes of the Norton variety was run at one temperature beginning September 24. The data given in Table II, show a marked retardation of ripening at 68 degrees F (relative humidity 90 per cent) from the CH_3Br treatments.

Two series of "pink" fruits were studied, one of Pearson and the

TABLE I—THE EFFECT OF CH_3Br ON THE RIPENING OF 133-6 TOMATOES UNDER DIFFERENT STORAGE CONDITIONS

Treatment Per 1000 Cubic Feet	Number at Each Stage of Maturity After 13 Days at 80 Degrees F			Number at Each Stage of Maturity After 15 Days at 68 Degrees F			Number at Each Stage of Maturity After 10 Days at 50 Degrees F and 14 Days at 68 Degrees F		
	Green	Turning	Ripe	Green	Turning	Ripe	Green	Turning	Ripe
Control	1	5	6	0	3	10	0	4	9
Control	2	5	6	0	3	10	0	3	10
1 pound—2 hours	3	5	5	0	8	5	1	10	2
1 pound—4 hours	2	4	7	0	7	6	0	7	6
2 pounds—1 hour	1	2	11	0	7	6	0	5	8
2 pounds—2 hours	0	6	7	0	8	5	0	5	8
2 pounds—4 hours	2	3	8	0	3	10	0	6	7

other of 133–6. Both were stored at 68 degrees F (relative humidity 90 per cent) following treatment. No differences in the rate of ripening was observed between the controls and the treated fruits. Jones (1) stated that methyl-bromide fumigation caused a delay in the coloring at room temperature of 3 to 4 days in the case of "pinks" and 4 to 6 days for mature green tomatoes. He could discover no effect of the residual CH_3Br in the fruits on their quality.

As to the internal characteristics of the ripened fruits no consistent effects of the CH_3Br treatment were noted in the soluble solids, pH, or titratable acidity. When stored at 80 degrees F the fruits which were gassed longest and those which received the heavier concentrations seemed to have an insipid flavor. The commercially gassed fruits were in this group. The fruits which received the CH_3Br fumigation appeared in general to be somewhat softer when ripe than were the controls. Whenever decay was a problem it was more severe in the fruits treated with CH_3Br. When the fruits were ripened at 68 degrees F no striking differences in flavor were noted.

Respiration:—Respiration trials were conducted on four lots of "mature greens" and two of "pinks". There was good agreement in the tests with these lots. Fig. 1 shows a respiration series of a lot of "mature greens" of the 133–6 variety harvested September 23.

There is an immediate sharp increase in the respiration rate in all lots treated with CH_3Br, being as much as three times that of the controls. However, this high rate of respiration is not maintained, but drops off very sharply and within a period of 3 to 4 days it may be even less than that of the controls. The respiration rate of the fumigated

TABLE II—THE EFFECT OF CH_3Br ON THE RIPENING OF NORTON TOMATOES

Treatment Per 1000 Cubic Feet	Number at Each Stage of Maturity After 7 Days at 68 Degrees F		
	Green	Turning	Ripe
Control	4	9	14
1 pound—2 hours	8	12	7
1 pound—4 hours	7	12	8
1 pound—8 hours	8	11	4
2 pounds—1 hour	10	11	3
2 pounds—2 hours	10	16	0
2 pounds—4 hours	9	15	3

fruits then remains less than the controls until the fruits approach full color. In an earlier test some longer exposure and higher concentrations of CH_3Br were used, but the fruits were injured and decay set in. In the tests in Fig. 1, lot 7 treated with 2 pounds CH_3Br for 4 hours may have been slightly injured. Although care was exercised to remove from the mature green tomatoes all those which showed any sign of "breaking" there may have been some in this lot which were a little past the mature green stage. The total amount of CO_2 evolved during the respiration period was found to agree closely with the ripening rate, higher CO_2 indicating more rapid ripening.

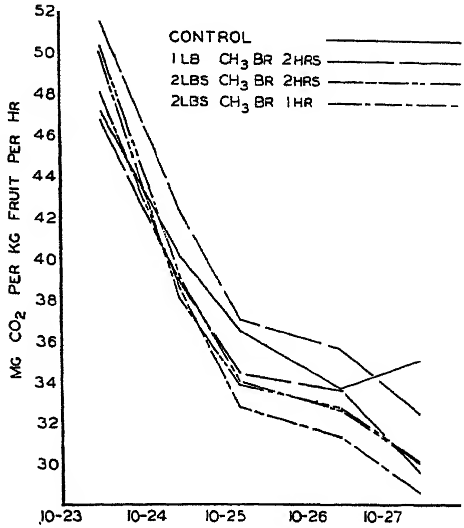

FIG. 2. The respiration curves obtained with "pink" fruits of the 133–6 variety placed in the chambers shortly after the fumigation period.

The respiration curves of the three other series with "mature greens" were in agreement with the data in Fig. 1.

Fig. 2 shows the respiration rate of "pinks" of the 133–6 variety harvested October 23. In this case the respiration measurements began shortly after the fumigation period was over. There was an immediate slight increase in the respiration rates of the fumigated lots followed within 24 hours by a small reduction in comparison to the control. In no case did the changes in respiration rates approach those in the "mature green" series. In the other lot of "pinks" aired for 24 hours after treatment the respiration rate of the gassed fruit had already dropped slightly below that of the control before the respiration study was initiated but again the differences were not great.

Discussion

There is an immediate speeding up of certain metabolic processes in "mature green" tomatoes when treated with CH_3Br as indicated by the accelerated respiration rate at 68 degrees F. This is similar to the effect of ethylene as demonstrated on various other fruits. However, the subsequent reduced metabolic activity does not agree with the ethylene effect and indicates that several metabolic processes may be involved in the methyl bromide effect. It may be that the enzymatic system is upset by fumigation with CH_3Br, but no enzyme studies have been run in conjunction with the tests reported here. It seems possible

that the activity of certain enzymes has been reduced and others increased. The respiration curve of fumigated fruits might well indicate that respirable materials were used up rapidly and depleted because of the slowing up of another process, thereby causing the end result to be a reduction in respiration rate. The data on ripening is in agreement with this idea, and indicate that the subject is worthy of further study, especially at temperatures of the magnitude of 80 degrees F.

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Potato Quality III. Relation of Soil Reaction, Irrigation and Mineral Nutrition to Cooking Quality[1]

By Ora Smith and L. B. Nash, *Cornell University, Ithaca, N. Y.*

The authors (1, 2, 3, 4, 5) have reported on various factors affecting the chemical composition, specific gravity and cooking quality of potatoes. In the present paper several additional factors are considered and others more thoroughly discussed than in the previous papers. A high correlation has been established between the specific gravity and texture of tubers. In some instances in this work only specific gravity determinations have been made as an index of the texture of the tubers.

Relation of Soil Reaction to Specific Gravity and Culinary Quality

From a series of 30 permanent soil reaction plots on which potatoes have been grown every year since 1932, with the exception of 1938, tubers were selected this year for cooking tests. In 1938 corn followed by rye was grown and plowed under as green manure. The soil reaction range in 1940 was from pH 4.88 to pH 7.55. One hundred tubers were selected from each of the 30 plots and the specific gravity of each lot determined by placing the tubers in a series of sodium chloride solutions with differences between solutions of 0.004 in specific gravity. The specific gravity of each tuber was considered the same as that of the solution in which it first sank, plus 0.002, when it had been started at the high end of the scale. Average specific gravity of each lot was determined by multiplying the number of tubers which sank in each solution by the specific gravity of that solution plus 0.002 and then dividing the sum of these figures by the total number of tubers. Only those tubers which had the same specific gravity as the average for the lot were selected from each lot for cooking tests. From five to eight tubers were selected for each cooking lot. The tubers were peeled before boiling in same size and kind of porcelain-lined containers. The same amount of water, same time for boiling and uniform gas flames were used with each experiment. A rating of 10 was given to any extremely mealy samples and lower numbers as mealiness decreased or degree of sogginess increased. Similarly samples remaining white one-half hour after boiling were rated 10 with lower numbers given as the degree of blackening increased. In each case the data in Table I are averages of five plots or tuber samples.

The data in Table I indicate that the average specific gravity of tubers increases when grown in soils of pH 4.88 to 5.30 to that of pH 6.73 to 7.19. A slight decrease in specific gravity occurs when grown in soils with slightly higher pH. The degree of mealiness likewise increases from the tubers of the lowest soil reaction to those

[1]Paper No. 228, Department of Vegetable Crops, Cornell University, Ithaca, New York.

TABLE I—Relation of Soil Reaction to Specific Gravity and Culinary Quality (Variety Smooth Rural)

Soil Reaction Range (pH)	Specific Gravity	Texture*	Color†
4.88–5.30	1.084	8.7	8.3
5.31–5.85	1.085	8.9	8.4
5.93–6.40	1.085	9.2	8.0
6.57–6.68	1.087	9.6	8.3
6.73–7.19	1.087	10.0	8.9
7.26–7.55	1.086	9.5	8.7

*Degree of mealiness from extremely mealy (10) to extremely soggy (0).
†Degree of blackening from none (10) to entire tuber dark (0).

grown at pH 6.73 to 7.19. Those grown at still higher pH range are slightly less mealy. There appears to be a good correlation between specific gravity and degree of mealiness. The degree of blackening occurring in samples grown in ranges of reaction of pH 6.57 to 6.68 or lower are very similar, all showing a considerable amount at the stem ends of the tubers. At reactions between pH 6.73 and pH 7.55 there was considerably less blackening which also was confined to the stem ends of the tubers. Analyses of these soils in 1936 (1) showed that at the higher pH ranges the largest amounts of soluble calcium, phosphorus and magnesium were found. In a later section of this paper it is indicated that calcium may be an important ion in increasing mealiness of tubers.

Effect of Irrigation and Rate of Fertilizer Application on Culinary Quality

Tubers were grown on a silt loam soil in plots which had been fertilized with 1,000, 1,500, 2,000, 2,500 and 3,000 pounds of 4–8–8 fertilizer to the acre and receiving water only in the form of rainfall. Similar plots received the same rates of fertilizer application but in addition to rainfall, a series of overhead irrigations were made in July, August and September, totaling 4.52 acre inches of water. Fifty to 100 tubers were selected from each of the above plots, in duplicate, the specific gravity of each lot and the cooking tests being made as explained in the preceding section. Each figure in Table II is the average of duplicate determinations.

TABLE II—Effect of Irrigation and Rate of Fertilizer Application on Culinary Quality, Dry Weight and Specific Gravity of Tubers (Variety Smooth Rural)

Rate of Fertilizer Application (Pounds/Acre)	Irrigated				Not Irrigated			
	Average Specific Gravity	Dry Weight (Per Cent)	Texture*	Color†	Average Specific Gravity	Dry Weight (Per Cent)	Texture*	Color†
1000	1.087	23.34	10	9.25	1.097	25.19	10	9
1500	1.088	23.45	10	7.75	1.091	23.76	10	8
2000	1.083	22.70	9	7.75	1.084	22.57	9	8.25
2500	1.079	21.67	8	8.50	1.082	22.13	8.75	6.75
3000	1.078	21.14	7.5	6.25	1.084	22.75	8.75	8.5

*†See footnotes Table I.

In both the irrigated and non-irrigated lots in general there is a decrease in the specific gravity and percentage dry weight of the tubers as the amount of fertilizer application increases from 1,000 pounds to 3,000 pounds to the acre. Tubers which had been grown with irrigation had a lower specific gravity at each of the rates of fertilizer application than tubers which had received no irrigation. This was true also with per cent dry weight at all rates of application except that of 2,000 pounds. Although the average specific gravity of the irrigated tubers grown at 1,000, 1,500 and 2,000 pounds per acre applications was lower than the non-irrigated tubers with the same fertilizer treatments, no texture differences were detected. All rated mealy or very mealy. At the higher rates of fertilizer application, however, irrigated tubers were less mealy than those not receiving irrigation at the same rate of fertilizer application. In both the irrigated and non-irrigated lots, the tubers receiving heaviest application of fertilizer were the least mealy.

There appears to be no consistent differences in degree of blackening at any rate of fertilizer application between irrigated and non-irrigated tubers. There is in general, however, an increase in the degree of blackening as the rate of fertilizer application increases. This is more marked in the irrigated than in the non-irrigated tubers.

Relation of Ratio of Nitrogen, Phosphorus and Potassium to Culinary Quality

Row applications at time of planting were made of eight combinations of amounts of nitrogen, phosphorus and potassium as shown in Table III. These tubers of the Green Mountain variety were grown on Long Island in a silt loam soil. Approximately 60 tubers were selected in duplicate from each of the eight fertilizer treatments and the specific gravity, dry weight and culinary quality determined as mentioned in a preceding section. All data in Table III are averages of duplicate determinations.

In all four sets of comparisons of low and high potash applications with the nitrogen and phosphorus remaining the same in each comparison (treatments 1–3, 2–4, 5–7, 6–8) tubers from plants receiving most potash had a lower specific gravity, lower dry weight per cent and lower texture rating than those receiving least potash. Similarly those from high nitrogen treatments had a lower specific gravity, lower

TABLE III—Relation of Ratio of Nitrogen, Phosphorus and Potassium to Culinary Quality, Dry Weight and Specific Gravity of Tubers (Variety Green Mountain)

Treatment No.‡	Pounds Per Acre $N-P_2O_5-K_2O$	Specific Gravity	Dry Weight (Per Cent)	Texture*	Color†
1	60–120– 80	1.085	23.20	5.75	10
2	60–200– 80	1.086	22.65	7.00	10
3	60–120–200	1.081	22.41	4.75	10
4	60–200–200	1.081	21.92	3.75	10
5	120–120– 80	1.083	22.28	3.25	10
6	120–200– 80	1.081	21.76	2.75	10
7	120–120–200	1.079	21.72	3.00	10
8	120–200–200	1.079	21.53	2.25	10

*†See footnotes Table I.
‡These tubers were kindly furnished by Prof. P. H. Wessels.

dry weight per cent and lower texture rating than those from low nitrogen treatments (1–5, 2–6, 3–7, 4–8). On the other hand there were no consistent differences in specific gravity of tubers grown with high and with low applications of P_2O_5 although in most instances high phosphorus applications resulted in decreased per cent of dry weight and decreased texture rating. Therefore, the most mealy potatoes were those from the lowest applications of nitrogen and potash and decreased in mealiness with increases in the amounts of nitrogen, phosphorus and potash applied.

All lots were rated rather low in texture as none was mealy. All were classed as slightly mealy to very soggy. Although in specific gravity these lots compared favorably with many grown in various places in upstate New York, the tubers when cooked were much less mealy. The reasons for these differences have not yet been detected.

No color differences in tubers of any of the treatments could be detected as no blackening was noticeable in any of the samples.

Relation of Various Salt Applications to Specific Gravity of Tubers

In addition to a broadcast application of 500 pounds to the acre of 5–10–5 fertilizer. 1 ton per acre of each of the substances listed in Table IV or ½ ton per acre of each of two salts were applied in the row at planting time to a silty clay loam soil. Nothing was applied to one series of plots which served as a check. Fifty to 100 tubers were taken from each treatment at each date of harvest for specific gravity determinations. The results are presented in Table IV.

In every instance, tubers harvested immature had a lower specific gravity than mature tubers of the same fertilizer treatment. Results of other experiments not reported here indicate that the lower specific gravity of immature tubers is not due to size of tuber as such, but is owing to lower dry weight and starch per cent factors which are associated with immature tubers. Tubers grown with calcium chloride applications had a higher specific gravity than those with potas-

TABLE IV—Relation of Various Salt Applications to Specific Gravity of Tubers (Variety Smooth Rural)

Treatment—1 Ton Per Acre*	Specific Gravity	
	Immature Tubers Harvested Aug 29	Mature Tubers Harvested Oct 19
Potassium chloride	1.058	1.071
Sodium chloride	1.060	1.073
Magnesium chloride	1.067	1.072
Calcium chloride	1.067	1.076
½ Potassium chloride, ½ sodium chloride	1.066	1.072
½ Calcium chloride, ½ magnesium chloride	1.062	1.074
Calcium sulfate	1.068	1.084
Magnesium sulfate	1.070	1.083
½ Calcium sulfate, ½ magnesium sulfate	1.070	1.088
20 Per Cent superphosphate	1.073	1.086
Hydrated lime	1.074	1.087
None	1.075	1.090

*All plots received 500 pounds 5–10–5 per acre broadcast in addition to these treatments.

sium chloride while those of magnesium and sodium chloride ranged between these two salts. In every case with the same cations the chloride form of salt produced tubers of lower specific gravity than the sulfate form. Hydrated lime and superphosphate treatments produced tubers with high specific gravities. The tubers of highest specific gravity were those grown with no additional fertilizer treatment.

Other lots of potatoes were grown in the greenhouse during the summer months in sand cultures to which solutions of altered K, Ca, Cl and SO_4 ions were applied as indicated in Table V.

TABLE V—Effect of Various Ions on the Specific Gravity of Tubers

	Low K, High Ca } Cl	Low K, High Ca } SO_4	High K, Low Ca } Cl	High K, Low Ca } SO_4
Specific Gravity.....	1.057	1.064	1.058	1.065

Results of the specific gravity measurements of these tubers and observations of the plants during the growing season indicated that the chloride ion is more involved in the reduction of specific gravity of tubers than the potassium ion and that the sulfate ion is more important in increasing specific gravity of the tuber than the calcium ion.

Conclusions

The average specific gravity and degree of mealiness increases in tubers when grown in a soil of pH 4.88 to 5.30 to that of pH 6.73 to 7.19 and decreases slightly at pH 7.26 to 7.55. Least blackening of cooked potatoes occurred at the higher pH ranges.

In general there was a decrease in the specific gravity and dry weight percentage of tubers as the fertilizer applications were increased from 1,000 to 3,000 pounds to the acre; irrigated tubers being lower at each rate of application than those not irrigated. At the higher rates of application irrigated tubers were less mealy than the non-irrigated tubers. In general there is an increase in the degree of blackening of tubers as the rate of fertilizer application increases.

Tubers from plants receiving heaviest potash and nitrogen applications had lower specific gravity, lower dry weight percentage and lower texture rating than tubers receiving least potash and nitrogen. No blackening occurred in tubers of any treatment.

Immature tubers had a lower specific gravity than mature tubers of the same fertilizer treatment.

With the same cations the chloride form of salt produced tubers of lower specific gravity than the sulfate form. Calcium chloride applications produced tubers of higher specific gravity than equal applications of potassium chloride.

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A Rare Abnormality in Stored Potato Tubers[1]

By E. V. HARDENBURG, *Cornell University, Ithaca, N. Y.*

IN MAY 1940, the author's attention was called to an abnormal condition existing in a lot of Bliss Triumph potatoes stored in the house-cellar of a resident of Ithaca, New York. Until about mid-winter, these potatoes had been of very satisfactory culinary quality, but as the season progressed, an internal condition developed making a large portion of the tubers inedible. A casual inspection of several bisected tubers led to the hasty assumption that rhizomes of nut grass, *Cyperus esculentus,* or of quack grass, *Agropyron repens,* had entered the tubers during the growth period. On further dissection of the infested tubers, it was discovered that the internal strands permeating the tissue were roots originating at the base of the apical sprout. Over one-half of the tubers were affected in this way. In no case, were any roots developed externally and nearly all tubers were in a fairly firm, apically-dominant sprout condition. Each affected tuber could be readily identified without cutting, by the corrugated or veined appearance of the epidermis caused by internal pressure of the potato roots beneath, see Fig. 1 (A). In the author's opinion, this is the only recorded instance of the occurrence of internal roots in *Solanum tuberosum.*

The occurrence of internal sprouts resulting in tubers within tubers was noted by Gager (1) in 1911 and by Stewart (3) in 1918. Internal tubers have been observed by many others and are known to occur occasionally in tubers stored overlong in damp cellars. The specimens

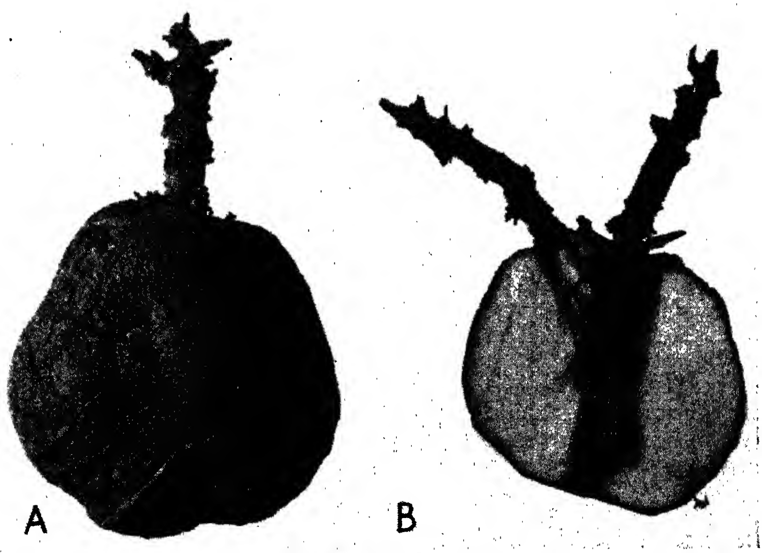

FIG. 1. Internal roots in *Solanum tuberosum,* variety Bliss Triumph. Note (A) Veining due to root pressure. (B) Internal roots in *Solanum tuberosum,* variety Bliss Triumph. Roots confined mainly to inner medulla.

[1]Paper No. 225, Dept. Vegetable Crops, Cornell University, Ithaca, N. Y.

noted by Stewart were found in a cool, damp, dark cellar while those noted by Gager and others observed by myself were stored under cool, dry, dimly lighted conditions. In each case, both the internal tubers and the inverted sprouts were able easily to emerge from the parent tuber by penetrating the epidermis from within. Gager observed that "numerous fibrous roots grew out from the branches, and they seemed, for the most part, to be confined in their growth to the channels made by the stem". Other investigators (1), have found that not only potato roots but roots of Vicia, Pisum, and Lupinus can readily penetrate living or wounded tissue but never the periderm. The occurrence of inverted sprouts and internal tubers in *Solanum tuberosum* has been ascribed as possibly due to reversed sprout polarity but no satisfactory substantiating proof has been offered. Similarly, no evidence has been found to explain either sprout or root penetration on the basis of enzyme secretion by the sprout or root tip. It has been concluded that both root and sprout penetration must be accounted for on the basis of mechanical pressure alone.

Difficult as it seems to be to explain inverted sprouts, it is equally difficult to account for internal roots in potato tubers. Potato root development is generally favored by humid, well aerated conditions. After prolonged storage under such conditions, whorls of roots commonly form externally at the base of the apical sprout. Pertinent to the subject of this paper, the roots originated from and at the base of the sprout but in every case, just beneath the periderm as shown in Fig. 1 (B). Storage conditions in this case, were dry, dimly lighted, and of a temperature range of 40 to 50 degrees F. Typically, these adventitious roots were confined in their development, to the inner medulla until the root tips reached the base of the tuber. Being unable to pierce the epidermis, thereafter they branched and ramified throughout the cortical layer subcutaneously. The fact that development was mainly within the inner medulla or least dense portion of the tuber may lend further emphasis to the theory that mechanical pressure alone is the primary basis of penetration.

According to Hayward (2) adventitious roots of the potato "frequently occur in groups of three and their point of origin is in the pericyclic region of the subterranean portion of the stele in close proximity to a nodal plate". This means that such roots originate well beneath the sprout cortex. In the dry, dimly lighted storage involved in this instance conditions were favorable for the development of thick, slightly green sprouts but unfavorable for the development of external roots. The writer believes, therefore, that nutrients translocated from the apical sprouts stimulated root formation below the level of the tuber epidermis. Once these adventitious roots were initiated, they were unable to penetrate the periderm and subsequently developed internally.

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Direct Seeding of Tomatoes vs Southern-Grown Plants[1]

By E. S. Haber, *Iowa Agricultural Experiment Station, Ames, Ia.*

MOST of the canners in Iowa plant southern-grown tomato plants. Because of the low yields occasionally secured with southern-grown plants and the successful production of tomatoes by the direct-seeding method in certain sections outside of Iowa, considerable interest has developed in the latter method. Advantages claimed for direct-seeding are that it is less expensive; greater yields are secured; diseases are reduced and poor stands are eliminated. The growing season in central and northern Iowa is not long enough to permit the canners to use late varieties, such as Marglobe and Stone. Soils are heavy in this area and warm up slowly in the spring. These experiments were initiated in 1939 to determine if the direct-seeding method was practical in this, the northern limit of the tomato canning belt.

The same strain of seed of each variety was used for the treatments. The Marshall Canning Company furnished the seed of the Harris Early Stone variety for the home-grown plants and direct seeding. The same strain of seed was sent to Hope, Arkansas, for the production of plants for their commercial acreage. The Indiana Baltimore seed was furnished by the Iowa Canning Company and handled the same as the Harris Early Stone.

The seed, after treating with cuprocide, was drilled in rows 5 feet apart on April 22, 1939, at ½ inch depth. Because of dry soil the seed failed to germinate promptly and on May 10, a second seeding was drilled 6 inches from the original drilled rows at a depth of 1½ inches. Both seedings appeared above ground a week later after a shower. When 6 inches high, the plants were thinned and spaced 4 feet apart in the row. On May 15, the home-grown plants were planted. The seed of these plants was sown April 1 in the greenhouse, transplanted to flats 2 weeks later and hardened slightly a week before transplanting to the field. On May 24, the southern-grown plants received from the canning companies were planted. The design used was complete randomized blocks with 10 replications and 10 plants in each replication planted in a single row. All plots were harvested twice each week.

TABLE I—Tons of Tomatoes of U. S. Canning Grade No. 1 Per Acre in 1939

	Direct Seeding	Home-Grown Plants	Southern Plants
Harris Early Stone.......	9.6	12.8	8.9
Indiana Baltimore........	9.8	11.1	11.3

**L.S.D. =0.96 ton.

Home-grown plants of the Harris Early Stone variety produced more tomatoes than southern-grown or direct-seeded plants, but there

[1]Journal Paper No. J-812 of the Iowa Agricultural Experiment Station. Project 316.

was not a significant difference between southern-grown and direct-seeded plants. Home-grown and southern-grown plants of the Indiana Baltimore produced about the same yield, but both produced significantly greater yields than the direct-seeded plants. Septoria leaf spot was more serious on the Harris Early Stone variety than on the Indiana Baltimore, but no differences were noticeable between treatments within a variety. All plants were practically defoliated by September 15, 2 weeks before the first killing frost.

In 1940, the procedure was changed to determine the effects of seeding date on the yields. Home-grown plants were omitted since very little of the canning acreage in Iowa is planted with home-grown plants. The procedure was the same as in 1939. The canning companies furnished the seed and plants to eliminate the possibilities of strain variation. The four seeding dates are given in Table II. Southern-grown plants of the Harris Early Stone variety were planted May 18, and of the Indiana Baltimore variety on May 27. The same experimental design was used. Seed was drilled at 1-inch depth.

TABLE II—Tons of Tomatoes of U. S. Canning Grade No. 1 Per Acre in 1940

	Southern Plants	Seed Sown			
		April 15	May 1	May 15	June 1
Harris Early Stone..	12.8	8.5	6.7	5.4	2.3
Indiana Baltimore...	10.4	8.2	7.3	4.6	1.1

**L.S.D. = 1.9 ton.

All direct-seeded tomato plants yielded significantly less tomatoes than southern-grown plants in both varieties. The later the seeding date, the smaller was the yield. Results in 1940 are not consistent with those of 1939. Direct-seeding in 1939 with the Harris Early Stone variety equaled southern-grown plants, whereas in 1940 none of the seedings of this variety irrespective of planting date produced as much as the southern-grown plants. Weather conditions were quite different in the two seasons. August was a dry month in 1939, and very wet (over 15 inches of rain) in 1940. This caused rotting of many fruits before ripening in 1940. Septoria leaf spot, serious in 1939, was of no consequence in 1940.

From these results it may be concluded that the canners may not expect any more consistent yields, year after year, by direct-seeding than by the use of southern-grown plants if the latter are well-grown and fairly disease-free.

The Effect of the Topping of Young Tomato Plants on Fruit Set and Yield[1]

By K. C. Westover, *West Virginia Agricultural Experiment Station, Morgantown, W. Va.*

THE following experiments were motivated by the results of the recent investigations of Porter (1, 2) and Brasher and Westover (3) in which they found that the field performance of tender tomato plants was superior to that of plants which had been hardened in the usual manner. They were designed to determine the effect of the topping of young tomato plants on maturity, fruit set, and yield and to ascertain if this treatment affected different varieties in the same manner. They were also intended to give practical information concerning the feasibility of topping rather than resorting to the usual hardening practices as a means of "holding" young tender plants during adverse planting conditions until they could be moved to the field.

The Early Baltimore and Marvelous varieties of tomatoes were used. Under conditions which prevail in the medium altitudes of West Virginia, the first is considered as moderately early and the other as late. All the plants used in these studies were grown in the University greenhouse at Morgantown. Those for the 1938 plantings were flat-grown, while those for the plantings in 1939 and 1940 were grown in 3-inch pots. The 1938 and 1939 plantings were located at Reedsville, West Virginia, at an altitude of 1,800 feet on a moderately fertile Dekalb silt loam soil of good tilth. The 1940 planting, on the University Horticultural farm at Morgantown, at an altitude of approximately 1,100 feet, was on a Tilsit silt loam of good tilth.

The topping treatment consisted merely of pinching off the main stem above the second leaf (node) of a desired number of uniformly selected young tomato plants of each variety 10 days to 2 weeks before the plants were to be set in the field. A suitable number of untreated or normal plants were retained as checks and for border planting. The same spacing, row lengths, and planting scheme were used each season. Only the number of plants in the treatments and replications differed from year to year.

The plants were spaced every 5 feet in rows 5 feet apart. Individual check and topped plants from the Early Baltimore and Marvelous varieties, in the order named, occurred in this same sequence over the entire planting. The rows were 25 plants in length, and the first and the last plants were therefore of the same treatment, which resulted in a systematic arrangement of the treatments of both varieties from left to right as well as from front to rear. Guard rows bordered the plantings. Each year soil fertilization and cultural operations were uniform over the entire experimental area. Information of a more detailed nature will be given when the studies are considered separately.

During the harvest period, record was made of both the number and the weight of fruits to tenth-pound accuracy of the marketable and the

[1]Published with the approval of the Director, West Virginia Agricultural Experiment Station, as Scientific Paper No. 258.

total yields from each plant for the early as well as the entire producing season. The pickings occurred at frequent intervals, at which times all fruits regardless of size were gathered if they were sufficiently colored to satisfy market demand. Those large enough to meet the requirements for No. 1 grade were considered marketable. After the harvest season was over, the plants were stripped of all fruit in order to determine the effect of treatment on total set.

In the analysis of these individual plant yields, the mean values of the measurements for the plants of the two treatments of each variety and the differences between these mean values for the corresponding measurements, together with their respective probable errors, have been calculated. Differences between corresponding means three or more times their respective probable errors are regarded as significant. The data from the two varieties are treated independently.

As has been stated before, the plants used in the 1938 trials were flat-grown and about 9 inches tall when they were topped on May 15. At this time they showed "legginess" and were somewhat uneven in development. During the following 11 days until they were set in the field, the topped plants developed axillary growths and the check plants became over-long because of the crowding in the flats. By careful selection for uniformity of plant size, gauged primarily by the stem diameter at the base of the plant, 81 plants of each treatment from each of the varieties and a sufficient number for the guard rows were available. They were planted on May 26 under very favorable weather conditions. An inspection of the planting 2 days later showed all the plants to be erect and apparently to have suffered little from the setting operation. The first yield records were taken on August 8. The differences between the mean plant yields of the treatments for both varieties are shown in Table I.

TABLE I—Comparisons of Mean Plant Yields in Pounds from Normal and Topped Young Tomato Plants Grown at the Arthurdale Experiment Farm in 1938

Grade	Determination	Treatment	Early Yield†		Season's Yield	
			Yield	Difference	Yield	Difference
			Early Baltimore			
Marketable	Number	N	2.78±0.13	+0.72±0.23*	15.72±0.46	+0.09±0.70
		T	3.50±0.19		15.81±0.53	
	Weight	N	1.07±0.04	+0.32±0.08*	4.23±0.15	+0.57±0.23
		T	1.39±0.07		4.80±0.18	
Total	Number	N	3.69±0.16	+1.34±0.28*	20.52±0.63	+0.25±0.91
		T	5.03±0.23		20.77±0.66	
	Weight	N	1.28±0.05	+0.29±0.09*	5.60±0.18	+0.24±0.28
		T	1.57±0.08		5.84±0.21	
			Marvelous			
Marketable	Number	N	3.51±0.15	−0.01±0.23	14.84±0.55	−2.62±0.67*
		T	3.50±0.17		12.22±0.39	
	Weight	N	1.43±0.09	————	4.86±0.16	−0.87±0.21*
		T	1.43±0.07		3.99±0.13	
Total	Number	N	4.75±0.20	+0.02±0.32	18.12±0.58	−3.52±0.75*
		T	4.77±0.25		14.60±0.47	
	Weight	N	1.61±0.07	+0.06±0.09	5.54±0.19	−0.99±0.24*
		T	1.67±0.07		4.55±0.15	

*Denotes significant difference.
†August 12 to 30 inclusive.

The Early Baltimore plants which were topped are here shown to have outyielded the check plants definitely in both number and weight of marketable and total fruits for the early period between August 12 to 30 inclusive. The yields for the entire harvest season from the topped plants were greater, but the differences were not significant. The total fruit set was about the same for the plants of both treatments. In respect to the Marvelous plants it is seen that the early yields were about the same for both treatments. The yields from the check plants for the entire harvest season were decidedly greater, as was also the case with the total fruit set (see Table IV). This study shows the *topping treatment to have been advantageous with the Early Baltimore* variety but of no benefit to the Marvelous variety. It suggests that the response to the topping of young plants may differ with different varieties and that this treatment might be a means of efficiently holding "leggy" plants in an emergency.

The plants which were used in the 1939 planting were about 10 inches tall when they were topped on May 9. Although normal and desirable in other respects, they were somewhat over-tall from close spacing. Fourteen days later when they were set in the field, axillary growth development on the topped plants was well started, and the check plants had become somewhat "spindly". The plants were set in the field without noticeable check in growth. There were 110 plants in each of the treatments.

The results of the yield comparisons for this planting are given in Table II and they strongly indicate that the topped Early Baltimore plants yielded less throughout the harvest period and set fewer fruits throughout the entire season than did the normal or check plants.

The topped plants of the Marvelous variety yielded a greater number of marketable fruits for the early period between July 25 and August

TABLE II—COMPARISONS OF MEAN PLANT YIELDS IN POUNDS FROM NORMAL AND TOPPED YOUNG TOMATO PLANTS GROWN AT THE ARTHURDALE EXPERIMENT FARM IN 1939

Grade	Determination	Treatment	Early Yield†		Season's Yield	
			Yield	Difference	Yield	Difference
			Early Baltimore			
Marketable	Number	N	7.26±0.21	−0.43±0.30	20.47±0.44	−0.19±0.60
		T	6.83±0.22		20.28±0.41	
	Weight	N	2.09±0.07	−0.16±0.09	5.35±0.13	−0.27±0.18
		T	1.93±0.06		5.08±0.12	
Total	Number	N	9.92±0.25	−0.53±0.35	39.55±0.63	−2.22±0.88
		T	9.39±0.24		37.33±0.61	
	Weight	N	2.51±0.15	−0.31±0.16	7.16±0.13	−0.37±0.18
		T	2.20±0.06		6.79±0.12	
			Marvelous			
Marketable	Number	N	4.46±0.16	+0.35±0.23	20.04±0.41	+1.24±0.58
		T	4.81±0.16		21.27±0.41	
	Weight	N	1.94±0.05	−0.46±0.07*	5.04±0.10	+0.26±0.16
		T	1.48±0.05		5.30±0.11	
Total	Number	N	5.94±0.22	+0.81±0.28	33.63±0.63	−0.90±0.84
		T	6.75±0.18		32.73±0.55	
	Weight	N	1.41±0.05	+0.30±0.07*	6.42±0.13	+0.17±0.18
		T	1.71±0.05		6.59±0.13	

*Denotes significant difference.
†July 23 to August 16 inclusive.

16 inclusive, but they weighed less and were perhaps smaller. The same comparative results hold true for the entire producing season, except that the fruit weight apparently increased as the season progressed. The yield of unmarketable fruits from the topped plants was definitely greater in the early harvest period, but it seems to have decreased as the season advanced. Table IV shows that there was little difference between the plants of the two treatments in total fruit set.

This study shows the topping treatment to have had substantially the opposite effect as in 1938 with respect to varieties. The fact remains however that the topping treatment did increase early yields with the Marvelous variety.

The 1940 planting consisted of 100 plants of each treatment. On May 11, when the topping treatment was given, they were about 9 inches tall and had begun to show "legginess" because of crowding. The spacing between the plants was then increased to about 6 inches, and on May 27, 13 days later, when they were taken to the field, the axillary growths on the topped plants were at least 2 inches long, and the check plants were about 3 inches taller and not unduly spindling. Field conditions were favorable at the time of planting, and the plants later showed no appreciable effects from the change. Table III, in which the individual plant yields of the two treatments are compared, shows both varieties to have responded in much the same manner as in 1939.

The Early Baltimore plants which were topped are seen to have yielded a greater weight of marketable fruits during the early and the total harvest periods than did the check plants. The reverse is true in regard to the number of fruits. The fruits from the topped plants were evidently heavier and possibly larger. The check plants yielded

TABLE III—Comparison of Mean Plant Yields in Pounds from Normal and Topped Young Tomato Plants Grown on the Horticultural Farm at Morgantown in 1940

Grade	Determination	Treatment	Early Yield†		Season's Yield	
			Yield	Difference	Yield	Difference
			Early Baltimore			
Marketable	Number	N	8.94±0.28	−0.46±0.38	35.33±0.58	−0.61±0.86
		T	8.48±0.26		34.72±0.86	
	Weight	N	3.34±0.11	+0.07±0.16	12.86±0.36	+0.22±0.49
		T	3.41±0.11		13.08±0.33	
Total	Number	N	11.52±0.32	−1.67±0.51*	61.69±1.10	−4.74±1.43*
		T	9.85±0.40		56.95±0.92	
	Weight	N	3.72±0.12	−0.06±0.16	17.12±0.36	−0.90±0.44
		T	3.66±0.11		16.22±0.25	
			Marvelous			
Marketable	Number	N	8.97±0.26	+0.93±0.44	31.95±0.54	−0.53±0.75
		T	9.90±0.36		31.42±0.52	
	Weight	N	3.85±0.11	+0.50±0.16*	12.10±0.24	−0.18±0.33
		T	4.35±0.12		11.92±0.23	
Total	Number	N	10.11±0.30	−1.70±0.42*	51.24±0.95	−5.90±1.22*
		T	8.41±0.30		45.34±0.76	
	Weight	N	4.06±0.11	−0.40±0.16	15.64±0.24	−0.68±0.34
		T	3.66±0.12		14.96±0.22	

*Denotes significant difference.
†July 23 to August 16 inclusive.

a significantly greater number of fruits during the entire harvest period and had the largest total fruit set. The weight of fruits from the check plants was larger, but the difference was of no significance. On the other hand, the topped plants of the Marvelous variety yielded a significantly greater number of marketable fruits during the early harvest period between July 23 and August 16, and gave lower yields of unmarketable fruit than did the normal plants. Although not significant, the weight of the marketable fruits from the topped plants was also greater for this same period. However, the yields of marketable fruit for the entire harvest season were about the same for the plants of both treatments. The total yields of all grades for the harvest period were greatest from the normal plants. These results again suggest that the topped plants of both varieties tended to yield a greater weight of early marketable fruits and that these fruits were probably larger than those from the check plants. However, in each instance the topping treatment reduced the yields and the total fruit set (see Table IV) for the entire season. These results coincide closely with those obtained in 1939 and might lead one to expect the later varieties to lend themselves most readily to this treatment. That the early yields of one of the varieties was increased again emphasizes the possibility that the topping of young plants under certain conditions may be practical.

In the consideration of the results of these studies taken collectively, there seems to be little attendant information to account for the reversal in performance of the plants of the two treatments of a given variety from year to year and much less for the reversal in effect on the varieties themselves. That the plants were flat-grown one year and pot-grown in the succeeding years, and that the plants of a given treatment as well as a given variety gave contradictory results, would seem to indicate that some varieties, preferably those that are early, if grown under crowded conditions, are distinctly benefited by this treatment, while others, preferably medium or late varieties, are definitely injured. That the opposite is indicated is true if the plants are pot-grown. This assumption would seem questionable, since much information is available to show that tomato varieties may differ widely in both visible and abstract characteristics and yet generally respond

TABLE IV—COMPARISON OF SEASON'S MEAN FRUIT SET FROM NORMAL AND TOPPED TOMATO PLANTS (1938 TO 1940 INCLUSIVE)

Determination	Early Baltimore		Marvelous	
	Normal	Topped	Normal	Topped
		1938		
Number	39.95 ±0.79	39.94 ±0.87	37.22 ±0.94	30.33 ±0.68
Difference	−0.01 ±1.18		−6.89 ±1.16*	
		1939		
Number	41.89 ±0.69	39.95 ±0.62	38.73 ±0.71	37.96 ±0.60
Difference	−1.94 ±0.93		−0.77 ±0.93	
		1940		
Number	118.88 ±1.52	102.46 ±1.77	99.91 ±1.45	92.66 ±1.33
Difference	−16.42 ±2.33*		−6.25 ±1.97*	

*Denotes significant difference.

to a certain degree in the same manner to a given treatment, which markedly alters them physiologically. Numerous investigations are reported that have shown the slight effect on maturity, the increase of early yields, and the reduction of total yields which result from various systems of pruning and topping in the field after the plant is bearing fruit.

The results of these experiments agree in that the treatment tended to increase the early yields but reduced the season's yields and fruit set in the majority of cases. The increases in early yields are difficult to explain unless the growth-checking effect of the topping treatment during the early development of the plants was quickly outgrown, and an increase in fruit set resulted which contributed to the increased yields during the early season. Although the treatment response with respect to variety was not entirely consistent, the fact remains that the early yields of at least one of the varieties was increased each year, and the yield losses, if any, of the other variety were of little significance. The treatment definitely reduced total yields and fruit set. These studies indicate that under the existing conditions, the topping of young tomato plants as a means of "holding" them in an emergency has practical possibilities.

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Shortening of Dormancy in Potato Tubers[1]

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ETHYLENE chlorohydrin (CH_2ClCH_2OH) and various other substances promote rapid germination of newly harvested and therefore dormant potato tubers, according to Denny (2) and Denny and Miller (3). Tests have been carried out during the past 2 years to determine the practicability of using such treatments for seed potatoes shipped to Hawaii from the mainland for early fall planting.

METHODS

Except as otherwise mentioned, these experiments were with small whole seed tubers (weighing about 2 ounces) of the variety Bliss Triumph. In September of 1938 and of 1939, certified seed were harvested in the Red River Valley, North Dakota and shipped immediately to Hawaii. From the progeny of these seed, new seed were saved for experiments planted in the spring of 1939 and of 1940. The North Dakota and the Island-grown seed behaved similarly except as indicated below.

Seed tubers were treated by the method of Denny and Miller (3). Potatoes to be treated were placed in a closed container with a small dish containing liquid ethylene chlorohydrin and a wad of cotton or cheese cloth to facilitate its evaporation. As the chlorohydrin evaporated it was taken up by the potatoes. Either pure or 40 per cent technical ethylene chlorohydrin may be used, but the pure chemical was used here except as otherwise mentioned. As a large part of the chlorohydrin is taken up by the potatoes, the amount which should be used is dependent on the weight of potatoes to be treated and not on the air space within the treatment chamber.

In these experiments the seed tubers were treated in 1-gallon jars, 5-gallon cans, or 50-gallon drums, depending on the number of potatoes under test. Treatment and storage before planting were at room temperature, which was usually between 25 and 28 degrees C.

RESULTS

Treatment of Dormant Seed Potatoes:—In the spring of 1939, groups of 16 dormant tubers were treated with 1 cubic centimeter of liquid ethylene chlorohydrin per kilogram of tubers and planted in a sand bed. In a total of four experiments the time at which treatments were applied varied between 7 and 62 days after harvest. The 2- and 3-day treatments gave more rapid germination and less rotting of seed tubers than longer or shorter treatments. The optimum length of treatment did not change significantly with increasing age of the potatoes.

In each experiment tubers were stored for periods of 2, 7, and 14 days between the end of treatment and planting. Both percentage of germination and tolerance to longer-than-optimum treatment were

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TABLE I—GERMINATION OF ETHYLENE CHLOROHYDRIN TREATED POTATOES PLANTED IN SAND

Duration of Treatment (Days)	Treated 7 Days After Harvest; Examined 24 Days After Planting		Treated 19 Days After Harvest; Examined 30 Days After Planting	
	Rotted (Per Cent)	Sprouted (Per Cent)	Rotted (Per Cent)	Sprouted (Per Cent)
2 Days Storage Time Between Treatment and Planting				
1	6	50	12	56
2	0	44	6	81
3	6	75	44	44
4	12	69	88	12
Control	4	0	6	0
14 Days Storage Time Between Treatment and Planting				
1	0	22	11	72
2	0	61	0	100
3	0	83	0	100
4	0	66	11	89
Control	4	0	6	0

greatest in the groups which were stored 14 days after treatment. These groups were beginning to germinate when planted. The results of these experiments are shown in Table I.

In the spring of 1940 dormant tubers were treated in lots of 120 and planted in the field in three replications, each containing 40 tubers. Germination occurred most rapidly when the chlorohydrin was used at the rate of 0.9 cubic centimeters per kilogram of tubers for 2 or 3 days. One-day treatments with this amount of chlorohydrin and all treatments with 0.6 and 0.3 cubic centimeters of chlorohydrin per kilogram were much less effective. Other groups of tubers were treated for 2 or 3 days with 0.9 cubic centimeters chlorohydrin per kilogram, stored for 11 days in the laboratory, and then treated again for 1½ days. At the time of the second treatment the buds had already reached an average length of about 1 millimeter. One set of treatments was with seed harvested 17 days before the first treatment and the other with seed harvested 46 days before the first treatment. Planting was 23 days after the first treatment when sprouts 1 to 3 millimeters long were present. The checks showed no growth at that time. After planting, the plants which had emerged from the soil were counted at intervals. As shown in Table II, the 2- and 3-day single treatments were both effective in breaking dormancy, but they did not produce as rapid germination alone as when they were followed by a second treatment.

The second treatment injured or killed many of the buds which had begun to grow. Nevertheless, other buds grew out and within a few days there was more growth than in tubers which had received only one treatment. The second treatment caused rotting of some potatoes, however, in three of the four groups which were so treated. In the fourth group (17-day-old seed; first treatment 2 days) the buds showed relatively little growth — less than 1 millimeter — at the time of the second treatment, and almost no damage after the second treatment. Yet germination was much more rapid than in similar tubers which received only a single treatment. Apparently little or no rotting

TABLE II—EFFECT OF ETHYLENE CHLOROHYDRIN ON GERMINATION AND GROWTH OF DORMANT SEED POTATOES

Duration of First Treatment (Days)	Duration of Second Treatment (11 Days After First) (Days)	Per Cent Emergence From Soil at the Following Intervals After Planting*					Average Number of Stems per Seed Tuber
		10 Days	14 Days	21 Days	37 Days	65 Days	
17 Days Between Harvest and First Treatment							
2	None	0	1	53	68	84	1.8
3	None	3	8	63	85	92	1.7
2	1½	4	16	88	93	99	3.0
3	1½	6	28	78	80	86	3.2
None	None	0	1	3	4	43	1.4
46 Days Between Harvest and First Treatment							
2	None	12	32	97	99	99	2.4
3	None	8	29	94	98	100	2.0
2	1½	37	76	88	89	89	4.5
3	1½	31	67	85	85	85	4.7
None	None	0	1	30	58	87	1.4

*Planted 23 days after beginning of first treatment.

occurs if the second treatment is made as soon as development of the buds first becomes apparent rather than when they have reached a length of 1 millimeter or more.

Counts of the number of stems arising from these plants (made when they were approaching maturity) showed that the ethylene chlorohydrin also increased the number of stems per seed tuber. This increase was greatest for the treatments having the greatest accelerating effect on germination.

As was expected, yields were highest in the treatments which produced rapid and regular germination, and lowest in the untreated groups where some seed tubers failed to germinate until others were approaching maturity. The yields were very low, however, as the crop (though planted in cool weather) approached maturity when the weather was too warm for good potato production.

In the spring of 1940, four other experiments were carried out, in all of which a 3-day treatment with 0.9 cubic centimeters chlorohydrin per kilogram of tubers gave good results.

Non-dormant Seed Potatoes:—In the fall of 1939, the seed potatoes from the mainland had nearly passed through their dormant period when they reached Hawaii. At the time the treatments were applied they showed slight growth but the buds were less than 1 millimeter long. Lots of 200 seed tubers were treated with 0.8 cubic centimeters chlorohydrin per kilogram for periods of 1 to 4 days. They were then stored for 13 days and planted 1 foot apart in four replications of 50 tubers each. The treated potatoes germinated only about 5 days sooner than the untreated but non-dormant checks. The treated plants also matured and died slightly earlier than the checks. The crop was harvested 87 days after planting. The yields were reduced by early blight which attacked first the treated (and therefore older) groups and later the untreated (younger) groups. Treatments with 0.2 cubic centimeters chlorohydrin per kilogram were tried but were less effective.

TABLE III—EFFECT OF ETHYLENE CHLOROHYDRIN ON GROWTH AND YIELD OF NON-DORMANT SEED POTATOES

Duration of Treatment (Days)	Per Cent Emergence 28 Days After Planting	Total Yield Per 100 Seed Planted (Pounds)†	Yield Per Plant (Total Yield Divided by Number of Seeds Which Grew) (Pounds)†	Average Number of Stems Per Hill‡	Average Weight Per Hill (Pounds)‡	Average Number of Tubers Per Hill‡
Control....	95	39.7	0.42	1.6	0.47	4.8
			Per Cent Increase Over Control			
1.........	95	21 ±9*	21 ±9*	41 ±15**	25 ± 9**	19 ± 9*
2.........	78	12 ±9	36 ±9**	73 ±16**	35 ±11**	32 ±12**
3.........	55	−9 ±9	56 ±9**	123 ±18**	——	——
4.........	57	−17 ±9	40 ±9**	102 ±19**	43 ±12**	47 ±12**

*Significant (P.<.05).
**Highly significant (P.<.01).
†The standard deviations in the third and fourth columns are based on analyses of variance for nine treatments, each replicated four times.
‡The last three columns represent one of the four replicates, from which all hills (except 3-day treatment) were weighed and counted individually.

The results of this experiment are shown in Table III. As in the experiments with dormant seed, the treatment increased the number of stems from each seed tuber. The 1-day treatment gave a 21 per cent increase in yield. The longer treatments (2, 3, and 4 days) killed part of the seed tubers, thereby reducing the total yield for these groups. However, the average yield for each seed tuber that germinated (*i.e.*, the total yield divided by the percentage of germination) was increased much more by the 2-, 3-, and 4-day treatments, with a maximum increase of 56 per cent for the 3-day treatment. The average number of tubers per hill was increased to about the same extent as the average yield per hill, showing that tuber size was not affected.

This was the only experiment in which 2- or 3-day treatments caused a reduction of germination below that of the controls. In three other experiments with non-dormant seed the percentage of germination was not reduced by the treatment. This suggests that, with better knowledge of the optimum conditions for treatment, 3-day treatments may give as consistent results with non-dormant tubers as they do with dormant ones. If so, they may also give more than the 21 per cent increase in yield reported here for the 1-day treatment.

Large Scale Treatments:—Four unopened 100-pound bags of potatoes were treated for 3 days in 50-gallon drums, one with pure ethylene chlorohydrin and the others with 40 per cent technical grade. The drums contained a fan, which was run for several hours after the drums were sealed and from time to time during the remainder of the treatment. In all cases the pan containing the ethylene chlorohydrin was dry at the end of the treatment. After treatment the bags were stored unopened for 10 to 13 days, after which the potatoes were planted.

The potatoes were removed from the bags in three portions representing top, middle, and bottom of the bag. In two of the bags these portions were again subdivided into outside (potatoes near the outside of the bag) and center (center portion of the bag). From each portion a sample of 150 potatoes was planted in three 50-foot rows located at

random in the test plot. Two weeks after planting, the average per cent emergence for these two bags was: top, outside, 67; top, inside, 64; middle, outside, 70; middle, inside, 74; bottom, outside, 70; bottom, inside, 72; untreated controls, 13. As the difference necessary for significance was 10 per cent, it may be seen that all parts of the bags were affected in about the same way. The other two bags also gave uniform germination.

Dip Treatment:—In a few experiments the ethylene chlorohydrin dip treatment was used (Denny (2), Stuart and Milstead (4)). When potatoes were dipped momentarily into a 6 per cent (by volume) ethylene chlorohydrin solution and stored without rinsing for 3 days in a sealed jar, germination was as rapid as in similar potatoes which received a 3-day gas treatment with 1.0 cubic centimeter of chlorohydrin per kilogram of potatoes. Subsequent experiments showed that similar potatoes, when dipped, retained about 12 cubic centimeters of solution per kilogram of potatoes. Thus they only received 6 per cent of this amount of chlorohydrin, or 0.72 cubic centimeters per kilogram. The dip treatment is less convenient to use than the gas treatment except for small lots of potatoes.

Treatment of Other Varieties:—Dormant Island-grown seed of varieties Bliss Triumph, British Queen, and two unnamed varieties were treated simultaneously for 3 days with 1.0 cubic centimeter chlorohydrin per kilogram of potatoes. Twenty-three days after treatment percentages of germination in the treated groups were, respectively, 93, 87, 100, and 93; in the untreated groups, 13, 73, 0, and 60.

Effect of Other Substances on Dormancy

Ethylene chlorohydrin has proved to be more effective than any other substance in producing rapid germination of dormant potato tubers. Denny (2) and Stuart and Milstead (4), however, also obtained good results with sodium thiocyanate. North Dakota grown seed potatoes were dipped momentarily in 1 and 2 per cent solutions of sodium thiocyanate and kept wet with the solutions for periods varying between 1 and 24 hours. They were then stored for 9 to 16 days before planting. The best results in 1938, (2 per cent solution for 3 hours) were inferior to those produced by ethylene chlorohydrin. When similar treatments were made in 1939, the seed was planted in

TABLE IV—Treatment of Potato Tubers with Phenyl-acetic Acid

Treatment	Average Length of Longest Eye, 28 Days After Treatment (Mm)	Per Cent Emergence	
		30 Days After Treatment	52 Days After Treatment
Phenyl-acetic acid vapor—3 days*	4.37	5	88
Phenyl-acetic acid dip—10 g/1	4.44	8	75
Phenyl-acetic acid dip— 1 g/1**	4.04	0	73
Control	4.39	15	75
Ethylene chlorohydrin gas treatment 0.9 cc/kg for 3 days	8.10	70	98

*This was the treatment used by Zimmerman and Hitchcock.
**Two lower concentrations were also tried without effect.

the field and grown to maturity. Neither germination nor subsequent growth was advanced by the treatment.

According to Zimmerman and Hitchcock (6), phenyl-acetic acid is effective in breaking the dormancy of potatoes. Several treatments were made in the spring of 1940 with this substance, as shown in Table IV. For each treatment, 40 tubers were planted in the field where records were made of the percentage emerged from the ground at various times, and 40 were kept in the laboratory at room temperature where the amount of growth was measured 28 days after treatment. The tubers were treated 66 days after harvest. These data fail to show any effect of phenyl-acetic acid upon germination.

Discussion and Conclusions

In the experiments described here treatments with 0.8 to 1.0 cubic centimeters of ethylene chlorohydrin per kilogram of potatoes for 3 days hastened germination without causing injury in every experiment with dormant potatoes. This is in agreement with the work of Denny and Miller (3), who have shown that good results are obtained when tubers are so treated that juice pressed from them after treatment contains between 5 and 15 cubic centimeters 0.1 M chlorohydrin or between 0.033 and 0.100 cubic centimeters pure chlorohydrin per 100 cubic centimeters of press juice. If potatoes are treated at the rate of 0.1 cubic centimeter per 100 grams (1.0 cubic centimeter per kilogram) of tubers, and if 100 grams of tubers give roughly 100 cubic centimeters of press juice, then it is only necessary for one-third of the chlorohydrin to be taken up and recovered in the press juice in order to give the minimum effective concentration in the press juice, while all of it may be taken up before the maximum concentration is exceeded. Denny and Miller recovered at least a third of the chlorohydrin in all treatments lasting 2 days or more at a temperature of 26 degrees C or over. At lower temperatures treatments will probably have to be somewhat longer in order to insure uptake of a sufficient amount of chlorohydrin.

Growth is stimulated even when treatment is applied at the time that the tuber is beginning to germinate. This is true both for the tubers which are passing naturally out of their dormant period and for those in which growth has been started by a previous chlorohydrin treatment. Germinating tubers, however, have in some cases been damaged by treatments lasting 3 days and by treatments made when the buds had reached a length of 1 millimeter or more. It is therefore recommended that tubers that are beginning to sprout should be treated only for 1 or 1½ days and only when the buds are less than 1 millimeter long.

Ethylene chlorohydrin treatment also increases the number of stems per seed tuber, as has also been reported by Werner (5). When non-dormant potatoes were treated (fall, 1939), the treated plants and controls grew at nearly the same time and had about the same growth period. The increase in average yield per plant (not counting those that failed to germinate) was roughly proportional to the increase in the number of stems. This suggests that the increased yield from the

treated seed is a result of the increased number of stems per hills. This hypothesis is supported by experiments of Claypool and Morris (1) who found that two-stem hills give twice as great a yield as one stem; three-stem somewhat greater than two; and four-stem slightly greater than three. Only in the four-stem hills did they find a slight decrease in tuber size. In view of this, the ethylene chlorohydrin treatment, when it increases the average number of stems per hill from between one and two to between three and five, may also be expected to increase the yield. Nevertheless it must be recognized that the effectiveness of increasing the number of stems will vary with such factors as planting distance and size of the plants at maturity.

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Frost Tolerance of Strains of Market Garden Peas[1]

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DURING the last several years breeding investigations have been under way with the objective of developing early, market garden peas resistant to Fusarium wilt (*Fusarium orthoceras* Appl. and Wr. var. *pisi* Linford). It has been necessary to move this work to various parts of the country and, in so doing, various problems not included in the original plans for the work have been encountered. Since 1936 most of this work has been carried on at Charleston, South Carolina. Temperatures at Charleston rise rapidly in the spring so that the only strains performing satisfactorily have been the early ones. It has also been possible in some years to obtain a fall crop as well as the usual spring one. Both spring and fall crops are exposed to the hazard of frosts so that observations have been made on reactions of the various strains to temperatures of 32 degrees F or below.

WEATHER, MATERIALS AND METHODS

On March 29, 1937 the temperature dropped to 30 degrees F while many strains of peas were in bloom. Most strains had their blossoms completely destroyed while a few were apparently not injured. Most of the uninjured blossoms were colored blossoms but some were white. In many cases the uninjured colored blossoms produced viable seeds, while the seeds obtained from most of the apparently uninjured white flowers either failed to develop properly or if developed were apparently normal but not viable. At no other time during the investigations have frosts occurred at blooming time so that additional information for this period in the life history of the pea plants has not been accumulated. Meanwhile, due to difficulties in maturing seed of the colored lines, they have all been lost or dropped.

In 1939 temperatures of 24, 21, and 31 degrees F occurred on February 23, 24, and 25 respectively. In some cases these frosts resulted in outright killing of the seedling plants (seed planted in mid-January), while in others the damage was slight or negligible. A planting made in September, 1939 was injured by frosts on November 2, 6, 7, 8, 9, 14 and 15 with temperatures of 30, 31, 28, 30, 19, 23 and 23 degrees respectively. These plants were hardened by successive light frosts and the 19 degrees temperature produced approximately the same damage as the temperatures occurring in February. In both the spring and fall crops of 1939 the injury occurred when most of the plants were in the third to fifth leaf stage. Soil moisture in both seasons was optimum or near optimum for good growth at the time of the frosts.

Injury was recorded on the basis of 0 for plants showing no injury; 1, for mild injury such as necrotic flecks or necrotic edges of leaves; 2, for medium injury with large necrotic areas; 3, severe injury with very large necrotic areas, but plants with sufficient vigor so that growth could be resumed promptly; 4, very severe injury with very large

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FIG. 1. Increase blocks of N 901, a frost susceptible strain (right), and N 902, a frost tolerant strain (left), 2 weeks after a temperature of 21 degrees F.

necrotic areas, but plants with reduced vigor so that growth resumption was delayed; and 5, dead. Fig. 1 shows an increase block of N 902, a frost tolerant strain, in comparison with a block of N 901, a susceptible strain.

In the spring planting, the material had been grouped and planted according to amount of seed available, promise of strains for breeding material, and so on. Careful and detailed notes were taken on frost damage to the advanced breeding material and on certain other strains, but detailed notes were not taken on damage to the entire three acres of breeding material. In the fall only certain selected strains were carried, so detailed notes were taken on all of them.

Both plantings were in randomized blocks in duplicate. Notes were taken about two weeks after the most severe frost in spring and fall. At first the notes were made on the basis of each plant rated separately and the rating of the plot determined by averaging the ratings of all plants per row. Since there were about 100 plants per row and the method time-consuming, it was decided to give the single row plots a rating without rating each plant. When this was done the figure obtained was very close to the average so the quicker method was used. Variance analyses were applied to the data.

Crosses represented in the material on which very careful notes were made were: Giant Stride x Progress, World Record x Progress, Kent Alderman x Progress, Sutton Excelsior x Giant Stride, and Little Marvel x (Thomas Laxton x Phenomenon). Segregates tested from these crosses were mostly in the fifth to eighth generation following the cross. Standard varieties used as checks were Progress, Hundredfold, and World Record. Kent Alderman and Giant Stride ordinarily do not set seed under Charleston conditions so they were omitted. World Record, an early variety with about the same observed frost tolerance as Kent Alderman, was used. No substitute for Giant Stride was attempted but it was observed in other places in the test. Phenomenon, which had previously shown some frost tolerance in Imperial Valley, California, was not available.

Results

Variance analyses applied to the data collected in the spring and fall of 1939 indicated that highly significant differences between strains tested existed in both seasons as shown by F values in excess of the 1 per cent level of significance. The difference required for significance was 0.73 units on the frost damage scale in the spring for the mean of two plots and 0.65 in the fall. In the spring planting four plots of each commercial variety were used in each series, so a significant difference between commercial varieties in the spring test is 0.13. Commercial varieties Progress, Hundredfold, and World Record were tolerant to frost in that order (Table I) and the differences were significant in the spring but only between Progress and World Record in the fall. Shortly after a damaging frost, Progress and Hundredfold appear damaged to the same extent but all observations here indicated that Progress recovers much more quickly. World Record is very susceptible to frost, shows very large lesions or wilting and appears to possess no ability to recover. Since the conditions existing in the spring were not entirely comparable to those existing in the fall and since the plot arrangements were not satisfactory for a combined variance analysis, it was not attempted. However, in spite of these differences the results obtained approached each other very closely.

In both spring and fall plantings there existed strains, derived from crosses, that were significantly more tolerant than the tested parent or parents and also strains that were less tolerant. The detailed average results are given in Table I.

Table I also contains a column showing the Fusarium wilt reaction of some of the strains. Some have been distributed for testing in the South and it is believed that a record of wilt resistance may be valuable to seedsmen and those attempting to produce these seed commercially. Resistance to Fusarium wilt was brought in to these crosses by Giant Stride, Kent Alderman, and World Record. However, a different strain of World Record was used in these frost resistance tests which is wilt susceptible.

Discussion

Since the original plantings in the spring of 1939 were for increases, observations and comparisons of breeding material, some parental varieties were omitted from the test that might otherwise have been included. Kent Alderman in a separate series in the field had a frost damage rating of nearly 5, while Giant Stride and Little Marvel with a rating of 4 each were intermediate between Progress and Hundredfold. Thomas Laxton was observed to react much like Hundredfold.

Most of the strains tested were in the fifth to eighth generation following the cross and appeared homozygous for most characteristics. However, some of those with heavy frost damage in the spring had a few survivors which appeared quite tolerant. None of those with a rating of 4 or more in the spring test produced sufficient seed for tests in the fall, while a few with ratings less than 4 failed to produce sufficient seed for further tests, for other reasons than frost damage.

TABLE I—REACTION OF STRAINS OF PEAS TO FROST AND TO FUSARIUM WILT (FOR THE FROST TESTS THEY WERE GROWN IN SINGLE ROW PLOTS, RANDOMIZED BLOCKS, AT CHARLESTON, S. C., FROST DAMAGE RATED ON SCALE OF 0 FOR NO DAMAGE TO 5 FOR DEAD)

Strain No.	Parentage:	Frost Damage Spring 1939 (Mean 2 Plots)	Frost Damage Fall 1939 (Mean 2 Plots)	Reaction to Fusarium Wilt
N 897	Giant Stride × Progress	2.00†	2.25	Resistant
N 898	Giant Stride × Progress	3.25	3.25	Segregating
N 899	Giant Stride × Progress	3.25	3.25	Resistant
N 900	Giant Stride × Progress	3.00	3.00	Resistant
N 901	Giant Stride × Sutton Excelsior	4.25	—	—
N 883	Progress	3.50*	3.75	Susceptible
N 884	Hundredfold	4.35*	4.25	Susceptible
C 25	World Record	4.91*	4.75	Susceptible
N 902	Kent Alderman × Progress	1.75	1.75	Susceptible (?)
N 903	Giant Stride × Progress	3.00	3.00	Resistant
N 904	Giant Stride × Progress	3.50	3.25	Resistant
N 905	Giant Stride × Progress	3.75	3.50	Segregating
N 906	Giant Stride × Progress	3.00	3.25	Segregating
N 907	Giant Stride × Progress	2.75	3.00	Segregating
N 909	Little Marvel × (Thomas Laxton × Phenomenon)	3.25	3.00	Susceptible
N 910	Little Marvel × (Thomas Laxton × Phenomenon)	2.75	3.00	Resistant
N 911	Little Marvel × (Thomas Laxton × Phenomenon)	3.50	3.25	Resistant
N 912	Giant Stride × Progress	3.00	2.75	Segregating
N 913	Giant Stride × Sutton Excelsior	4.65	—	—
N 915	Giant Stride × Progress	3.50	—	—
N 916	Giant Stride × Progress	3.50	3.25	Resistant
N 917	Giant Stride × Progress	2.25	2.50	Resistant
N 918	Giant Stride × Sutton Excelsior	4.40	—	—
N 919	Giant Stride × Sutton Excelsior	4.65	—	—
N 922	Kent Alderman × Progress	3.00	3.25	Segregating
N 925	Kent Alderman × Progress	4.50	3.75	—
N 929	Kent Alderman × Progress	3.25	3.25	Segregating
N 930	Kent Alderman × Progress	4.00	4.00	Segregating
N 932	Kent Alderman × Progress	3.00	—	—
N 933	Kent Alderman × Progress	4.55	—	—
N 934	Kent Alderman × Progress	4.00	—	—
N 935	Kent Alderman × Progress	4.65	—	—
N 936	Kent Alderman × Progress	4.50	—	—
N 942	Kent Alderman × Progress	4.25	—	—
N 943	Kent Alderman × Progress	2.25	—	—
N 944	Kent Alderman × Progress	4.00	—	—
N 945	Kent Alderman × Progress	4.50	—	—
N 947	Kent Alderman × Progress	3.00	—	—
N 772B	World Record × Progress	2.00**	2.50	—
N 762A	Giant Stride × Progress	2.50**	2.75	—
N 761-1-2	Giant Stride × Progress	3.25**	3.25	—
N 297-2-2B	Giant Stride × Progress	3.00†	3.00	—

Standard Deviation Spring 1939 =0.36 Fall of 1939 =0.32
Sig. Diff. Mean of 2 Plots Spring 1939 =0.73 Fall of 1939 =0.65
*Sig. Diff. Mean of 8 check plots Spring 1939 =0.13.
†Occurred in only one series; excluded from variance analysis.
**Occurred in two series but not in same series as rest of group; excluded from variance analysis.

It is obvious that a field test depending upon natural temperatures occurring at various times in the life history of the plants must be interpreted with caution and too much dependence should not be placed in such results. However, the fact that two such sets of results check fairly closely with each other would indicate that tolerance to frost damage at a certain stage (or stages) does exist and that carefully controlled conditions for the evaluation of this tolerance would be justified.

CONCLUSIONS

Tests made during the spring and fall of 1939 with natural temperatures as low as 21 and 19 degrees F respectively indicated that during

a certain part of the seedling stage (3 to 5 leaves) certain breeding strains of peas and some commercial varieties reacted differentially to these temperatures. Many of the differences observed were significant and some of the frost tolerant strains have been released for further tests.

Strains N 902, N 897, N 900, N 903, N 906, N 910, N 912, N 917, N 922, N 943, N 772B, N 762A, and N 297–2–2B have appeared significantly better than the most tolerant commercial variety used (Progress) although certain strains seem to merit especial consideration; like N 902 with a frost damage rating of 1.75 in both seasons and N 897 with an average of 2.13. Numerically these figures do not mean much, but N 902 in an increase block in the spring of 1939 produced a normal yield while N 901 (with a rating of 4.25) was almost completely killed out in an adjacent block. Progress, while not particularly tolerant, was decidedly less injured than Hundredfold and Hundredfold much less than World Record.

Preliminary Studies on a New Muskmelon Hybrid

By J. C. Hoffman and H. D. Brown, *Ohio Agricultural Experiment Station, Columbus, Ohio*

During the summer of 1938, a selfed muskmelon from the variety Perfecto had an unusually small cavity, as compared with the other fruits of that progeny. The seed from this selfed fruit was planted the following year, and a hybrid matured having Milwaukee Market as the male parent. The seed from this cross was planted in the greenhouse and 15 selfed fruits were obtained.

The external appearance of all these fruits indicated that they represented the same phenotype. There was practically no netting, and ribbing was intermediate. The color of the flesh was deep orange, extending to a very thin green rim next to the rind. The quality was very good. Approximately 70 per cent of the fruits had a small cavity. The maturity was the same as for Milwaukee Market. Under Columbus conditions, the foliage has excellent field resistance to the common foliage diseases, in comparison with 80 other lines and varieties.

The F_2 generation was planted in the field breeding plots during the summer of 1940. The fruits of this crop resembled those of the F_1 generation, except that less than 1 per cent of these had large cavities. The other fruits, which were classified as having small cavities, ranged in cavity size from 78 to 184 milliliters; with an average of 126 milliliters.

Twenty of the small cavity fruits had an average weight of 1,607 grams, or a volume of 1,632 milliliters.

The average density of these fruits was 0.985. There were three fruits which had a density of 1.023, 1.014 and 1.008. The average density of the sliced fruits was 0.998, the greatest density of any one slice was 1.029. The flesh appeared to be very firm and of good texture. When these densities are compared with those reported by Hoffman (2), the differences are highly significant.

Currence (1) reports that refractive index is a relatively accurate method of estimating quality. Wagner (3) reports a relationship between vitamin C and refractive index. The refractive index of the small cavity fruits, as measured by a Zeiss hand refractometer, averaged 1.3478, as compared with 10 other varieties with an average refractive index of 1.3445. This difference is highly significant. However, four of the varieties had an average refractive index significantly greater than the small cavity melon.

Regression data of weight on density has a correlation coefficient of 0.122, which is not significant. The relation between cavity volume and density is not significant, with a correlation of –0.445. The correlation between weight of fruit and cavity volume is 0.434, which is not significant. The correlation between weight of fruit and density of sliced fruit is –0.434. This also is not significant.

In contrast to this, Hoffman (2) reports a significant correlation between weight and density, cavity factor and density; weight and cavity factor, and weight of fruit and density of sliced fruit. The above

data on this small cavity muskmelon do not show such trends. This may be due to the extreme firm texture and very small cavity. The cavity that is present is completely filled with seed and placenta tissue.

As was found by Hoffman (2), the correlation between refractive index and density of sliced fruit was not significant. The correlation between these two factors on the small cavity fruits is –0.205.

Conclusions

Due to its very small cavity, firm texture, and good quality, this new hybrid may be of value in muskmelon breeding programs. It lacks netting, but crosses have been made to intensify this factor.

The foliage is very hardy under Columbus conditions, as compared with 80 other lines.

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Relative Rind Toughness Among Watermelon Varieties

By Ivan J. Kenny and D. R. Porter,[1] *University of California, Davis, Calif.*

IT IS recognized that there exists a marked difference in rind toughness among watermelon varieties. Under certain environmental conditions, fruits of such varieties as Klondike frequently explode while attached to the plant. Cracking tendency likewise varies among varieties during picking, hauling, loading, and transporting. General observations indicate that when grown under arid climatic conditions, Klondike cracking is much less severe than when grown in humid districts. Imperial Valley growers pick Klondike fruits in late afternoon or early evening, but wait until the following morning to remove from the field and load the fruits for shipment. Apparently, high temperature tends to strengthen the rind, but if fruits are picked early in the morning, very severe breakage occurs. By picking in late afternoon and delaying loading until the following morning, Imperial Valley growers successfully ship Klondike watermelons to Denver and Canada.

Is this cracking tendency a function of thin rinds, is it a function of cell structure, is it a function of climatic conditions, or is it due to a certain combination of these or other factors? This paper presents data on puncture resistance of the rinds of 10 varieties and measurement of cell wall thickness of three representative types, previously found to vary in cracking tendency.

A standard fruit pressure tester described by Magness (2) was used to measure the relative rind toughness. The plunger point used by pomologists to determine fruit maturity in pears was too large to puncture the rind of Thurmond Grey, hence a plunger point was milled 0.199 inches in diameter. This plunger point punctured the Thurmond Grey rind at the highest reading on the scale (30 pounds). A sliding collar on the pressure tester remained at the correct reading on the scale after the plunger point had gone through the rind. Five punctures were made approximately equidistant from each other around the middle of the mature melon. Three punctures were made at a distance of 1 inch from the peduncle and three a similar distance from the blossom scar. The pressure tester was held as nearly as possible perpendicular to a tangent at the point of contact with the fruit. No difference was noted between the puncture taken at the soil spot and the other four punctures around the middle of the watermelon. No appreciable difference was noted within the same variety between watermelons punctured several days before or after fruit maturity.

Table I gives the arithmetic means and standard deviations of the puncture pressures taken around the middle of mature fruits of 10 commercial watermelon varieties. Means of the puncture pressures at the extreme blossom and stem ends are also included to show the relationship of rind thoughness in various parts of the fruit. The data derived from tests made around the middle were found to be repre-

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TABLE I—RESISTANCE OF WATERMELON RINDS TO PUNCTURE (DAVIS, CALIFORNIA, 1938)

Variety	No. Fruits	Arithmetic Mean of Pounds Required to Puncture		
		Middle Portion	Blossom End	Stem End
Klondike R7	10	9.9±0.141	8.8	10.0
Dixie Queen	20	10.0±0.065	9.5	11.2
Stone Mountain	20	12.7±0.123	11.2	13.5
Kleckley Sweet	21	13.3±0.112	12.5	15.5
Northern Sweet	20	19.3±0.225	17.1	24.5
Hawksbury	20	22.4±0.148	20.5	26.9
Leesburg	10	22.6±0.202	19.8	29.6
Improved Kleckley Sweet Number 6	19	22.7±0.190	21.4	27.0
Tom Watson	20	24.3±0.225	22.3	17.9
Thurmond Grey	20	28.0±0.121	25.6	29.6
Average	—	18.5	16.9	20.6

sentative of the greater portion of the fruit and for that reason were selected for statistical treatment.

In Table II the puncture pressures taken at the middle of the fruits are analysed statistically to determine the significance of the mean puncture readings between varieties. Using the analysis of variance method, the F value obtained was 150. The F value for significance at the 1 per cent level was 2.54. The variation in puncture readings between varieties studied was therefore highly significant and indicates that the pressure tester is a satisfactory instrument with which to measure rind toughness between watermelon varieties.

In searching for a morphological reason for rind toughness three varieties were selected for comparison: Thurmond Grey with a very tough rind, Klondike R7 with a very tender rind and Klondike R16, (3) intermediate in rind toughness. Samples of rind extending from the epidermis down to, but not including, the heart flesh were taken beside the punctured hole at the middle of the fruit which came nearest to the arithmetic mean of all the puncture pressures in the variety. For this reason the sections studied were probably representative of the variety.

Samples of rind were killed and fixed in Karpechenko's fluid. The butyl alcohol series was used to embed the samples in paraffin. Sections were cut 10 microns thick and stained with Safranin and Fastgreen.

The outstanding difference between varieties was the cell wall thickness of the parenchyma cells composing the middle mesocarp of watermelon rinds. In the varieties having tough rinds the parenchyma cell walls just below the schlerenchyma layer (1) are uniformly thicker than those in the varieties having more tender rinds. Table III sum-

TABLE II—ANALYSIS OF VARIANCE OF PUNCTURE RESISTANCE BETWEEN WATERMELON VARIETIES (DATA FOR MIDDLE PORTION OF FRUITS)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	159	7353	46.2
Between varieties	9	6620	735.0
Within varieties	150	733	4.9

$F = \frac{735}{4.9} = 150$ F value for significance at the 1 per cent level is 2.54.

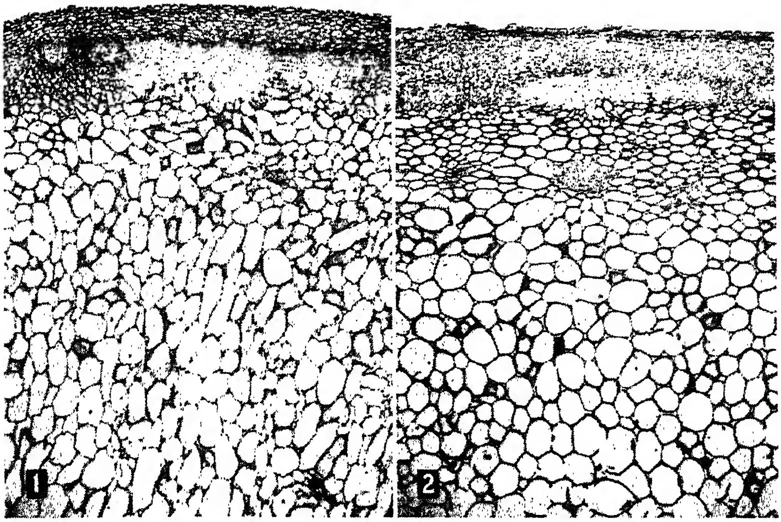

FIG. 1. Klondike R7—very tender rind. FIG. 2. Thurmond Grey—very tough rind.

marizes the filar micrometer measurements made of cell wall thickness in these three varieties. The units given at the various levels are divisions on the filar micrometer using a 100 × oil immersion objective. One division is equal to 0.000087 millimeter so that these measurements can be converted to millimeters by using this multiplying factor.

No attempt was made to make a correlation chart of puncture tests and cell wall thickness, but the number of slides from different varieties examined indicated that these thick walled parenchyma cells of the middle mesocarp probably contribute to rind toughness. Table III illustrates the close correlation in trend between puncture resistance and cell wall thickness in the first 10 millimeters of middle mesocarp tissue in three varieties.

A developmental study was made of the rind at various stages of fruit development in Thurmond Grey and Klondike R7. Samples of

TABLE III—CELL WALL THICKNESS IN THREE WATERMELON VARIETIES

Variety	Puncture		No. of Measurements at Each Level	Thickness of Walls at Middle Mesocarp at Respective Distances From Epidermis*						
	For Fruit Sectioned	Mean For Variety		.5 Mm	1 Mm	2 Mm	5 Mm	10 Mm	13 Mm	Average of First 10 Mm
Thurmond Grey......	30	28.0	20	31	31	26	24	24	6	27
Klondike R16	16	16.0	10	14	14	15	15	11	9	14
Klondine R7.	10	9.9	10	4	6	5	6	6	5	5

*Multiply by 0.000087 to convert to millimeters.

rind at the middle of the fruit were taken at time of anthesis and at 5-day intervals until fruit maturity. Ten days after anthesis small groups of stone cells were in evidence in both varieties just within the hypodermal layer. Fifteen days after anthesis the walls of the parenchyma cells composing the middle mesocarp in Thurmond Grey were almost as thick as those in a mature fruit. The puncture readings on this young fruit were also very near to the mean at the blossom, middle and stem ends of mature fruits. This suggests that the parenchyma cell walls of the middle mesocarp become thick in tough rinded varieties very early in the ontogeny of the developing rind.

Conclusion

The fruit pressure tester furnishes a satisfactory method of measuring rind toughness in watermelon varieties. It is a valuable tool for the breeder in selecting individual fruits possessing a tough rind. The layer of thick walled parenchyma cells extending from the schlerenchyma layer down into the middle mesocarp suggests a morphological explanation of toughness in watermelon rinds.

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Performance Trials of New "Baby" Bush Lima Beans Grown for Canning—A Progress Report

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THE purpose of this report is to present preliminary data to show the influence of date of planting and rate of seeding on the yield of some of the new varieties of lima beans developed for canning. These new types have already been described fully by Magruder and Frazier (4) and Huelsen (3).

Results of 1939 Trials

Five varieties were planted in quadruplicate on June 20th at College Park and four seed per foot were dropped by hand to insure a uniform stand for each variety. The plants were pulled at harvest, and the seeds were threshed from the pods in a pea and lima bean huller. Two plantings were made at Ridgely sub-station on the Eastern Shore on June 15 and July 6. The first was planted in quadruplicate and the second contained 10 replicates. Only three varieties, were included in the two plantings at Ridgely since sufficient seed of Baby Fordhook and Maryland Thick Seeded was not available for the large viner trials. These latter plantings were made with a two-row Iron Age seeder calibrated to drop the same number of seed per foot for each variety. The plants from the Ridgely plantings were put through a regulation pea and lima bean viner. The data on yield and stand of plants for the three plantings are presented in Table I.

Yields were adjusted on the basis of stand by the use of covariance as described by Mahoney and Baten (5). If there is a strong correlation between stand and yield for all varieties some efficiency will be gained by adjustment. If, however, one variety shows a negative and another a positive correlation adjustment will not correct this condition. Stand apparently did not influence yield in the College Park test as the rank or position of the varieties with respect to yield was not altered by adjustment. There was no significant difference in the performance of Henderson and Baby Fordhook and both were significantly better than the other three varieties.

TABLE I—Yield of Shelled Lima Beans per Acre Before and After Adjusted for Stand at Two Locations in Maryland (1939)

Variety	College Park Trial Planted May 21st			Early Trial—Ridgely Planted June 15th			Late Planting—Ridgely Planted July 6		
	Actual Yield	Yield Adjusted For Stand	Stand of Plants Per Yard	Actual Yield	Yield Adjusted For Stand	Stand of Plants Per Yard	Actual Yield	Yield Adjusted For Stand	Stand of Plants Per Yard
Henderson	1007	991	11.4	1560.1	1407.4	9.2	1976.1	1956.8	8.0
Early Baby Potato	787	794	8.7	1234.2	1379.6	4.1	1106.7	1125.5	3.6
Regular Baby Potato	720	732	8.0	975.6	983.7	6.4	770.0	770.7	5.7
Baby Fordhook	955	955	9.4	—	—	—	—	—	—
Maryland Thick Seeded	549	542	10.1	—	—	—	—	—	—
Dif. required for significance	123	129	—	207.5	210.9	1.65	134.6	139.0	2.3

At Ridgely, in the early planting, Early Baby Potato had less than half the number of plants as shown for Henderson and in this case stand was a factor in yield, since adjustment raised the yield so that it was no longer significantly lower than Henderson. The yield of the regular strain of Baby Potato was not influenced by stand, and adjustment did not change its rank.

In the late planting at Ridgely, Early Baby Potato again had less than one-half the stand of Henderson, but in this case the correlation between stand and yield though significant, was too low to be of any importance and adjustment did not change the rank of these three varieties for yield. Henderson out-yielded both of the new varieties, and the Early strain of Baby Potato out-yielded the regular strain.

TABLE II—Lima Bean Variety and Time of Planting Test (1940), Ridgely, Maryland*

Planting	Stand (No. Plants Per Yard)	Shelled Beans Per Acre (Lbs)	Per Cent Beans in Each Sieve Size				Per Cent White	Harvest Date	Number Days to Harvest
			No. 1	No. 2	No. 3	No. 4			
Baby Potato									
First planting	7.5	502	—	—	—	—	11	Sep 9	94
Second planting	5.7	666	28	20	37	14	4	Oct 3	115
Third planting	6.6	1311	27	15	33	25	3	Oct 11	98
Average		826							
Early Baby Potato									
First planting	7.2	744	—	—	—	—	21	Sep 9	94
Second planting	4.8	1257	16	18	46	19	7	Oct 3	115
Third planting	6.3	1993	25	16	36	24	6	Oct 8	95
Average		1331							
Henderson									
First planting	11.7	532	—	—	—	—	18	Aug 21	75
Second planting	6.6	1573	13	21	47	19	24	Sep 27	109
Third planting	6.9	2303	13	15	49	23	27	Oct 3	95
Average		1469							
Green Henderson									
First planting	8.4	666	—	—	—	—	15	Aug 29	83
Early Henderson									
First planting	5.4	339	—	—	—	—	22	Aug 21	75
Second planting	4.8	1601	11	21	46	22	32	Sep 27	109
Third planting	5.4	1959	11	16	46	27	21	Sep 27	84
Average		1300							
Maryland Thick Seeded									
First planting	9.6	260	—	—	—	—	22	Sep 2	87
Second planting	5.1	1289	46	39	15	0	13	Oct 3	115
Third planting	7.2	1358	50	34	16	0	4	Oct 4	91
Average		969							
Baby Fordhook									
First planting	6.0	847	—	—	—	—	16	Sep 9	94
Second planting	5.4	1140	26	24	40	9	10	Oct 3	115
Third planting	6.6	1355	21	16	49	14	4	Oct 4	91
Average		1114							

*Plots planted in quadruplicate.
Dates of planting: First—June 7; Second—June 20; and Third—July 5.
Difference required for significance between yields: First planting—127 pounds; Second planting—179 pounds; and Third planting—252 pounds.

Results of 1940 Trials

The season of 1940 was not at all typical of the average season in Maryland. May and June were exceptionally cool with heavy rains, and poor stands were obtained in the early plantings. Four dates of plantings were used in 1940. The first planting, made on May 25th, was so poor due to uneven stands and growth that it was plowed under. The next plantings were made June 7th, June 20th, and July 5th. The June 7th planting henceforth will be called the first planting for 1940. All variety plantings were made with a new single row Iron Age seeder which had been calibrated to deliver the same number of seed per foot for each variety, irrespective of seed size. The germination was lower on one variety and this was likewise taken into account in the calibration. The stand of plants, yield of shelled beans per acre, sieve sizes, and number of days to maturity for the different dates of planting are given in Table II.

It is evident that the earliest planting in 1940 produced the lowest yields. Plants came into bloom during the extremely hot, dry period in mid-July. Baby Fordhook and Early Baby Potato out-yielded Henderson in this planting. Maryland Thick Seeded and Early Henderson were significantly lower in yield than Henderson.

Unfortunately, a heavy local hail storm caused a great deal of damage to the second planting but fields adjoining, planted at the same time, which had not been touched by the hail produced yields averaging almost a ton per acre of shelled beans. The hail occurred early in July and did not occur during blooming. Henderson significantly out-yielded all other varieties in this planting with the exception of Early Henderson. Early Baby Potato, Maryland Thick Seeded, and Baby Fordhook produced yields that were approximately equal.

Henderson again out-yielded all of the newer varieties in the third

TABLE III—Lima Bean Rate of Seeding Test (1940), Ridgely, Maryland*

Rate of Seeding	Stand (No. Plants Per Yard)	Yield Shelled Beans Per Acre	Per Cent White Beans	Mean No. Seed Per Lb	Rate of Seeding (Lbs Per Acre)	Per Cent of Perfect Stand	Date of Harvest
			Early Baby Potato				
Regular rate	4.8	1257	7	1118	38.9	53.3	Oct 3
Heavy rate	6.9	1033	14	1118	58.4	51.1	Oct 3
Extra heavy rate	8.7	908	19	1118	77.9	48.3	Oct 3
			Henderson				
Regular rate	6.6	1573	24	1140	38.2	73.3	Sep 27
Heavy rate	8.4	1489	17	1140	57.3	62.2	Sep 27
Extra heavy rate	11.1	1661	19	1140	76.4	61.7	Sep 27
			Maryland Thick Seeded				
Regular rate	5.1	1289	13	1744	25.0	56.7	Oct 3
Heavy rate	9.0	1843	18	1744	37.5	66.7	Oct 4
Extra heavy rate	10.2	1675	16	1744	50.0	56.7	Oct 4
Difference required for significance	—	178	—	—	—	—	—

*Planted June 20 in two-row plots 180 feet long; planted in quadruplicate.
Rate of seeding: Regular—approximately 3.0 seeds per foot; heavy—approximately 4.5 seeds per foot; and extra heavy—approximately 6.0 seeds per foot.

planting. Early Baby Potato, however, was just barely lower than Henderson in this planting. Baby Potato, Maryland Thick Seeded, and Baby Fordhook produced yields which were approximately equal.

Three rates of seeding were used on three varieties at the second planting date, and by use of different seed plates in the Cole seed hopper and different cogs, it was possible to calibrate the drill to drop 3, 4.5 and 6 seed per foot after correcting for germination. The data on stand of plants, yields, mean number of seed per pound, and the per cent of a perfect stand for this trial are given in Table III.

It is clearly evident that there was no relationship between the rates of seeding and yield of Henderson. There was a strong negative correlation between rate of seeding or stand of plants and yield of Early Baby Potato. The yield of shelled beans at the regular rate (stand of 4.8 plants per yard) was significantly higher than the heavy or extra heavy rates of seeding. The difference in yield between the latter two rates was not significant.

There was a positive correlation between stand and yield for the small variety Maryland Thick Seeded. The yield at the regular rate of seeding was significantly lower than for the two other rates of seeding. The difference in yield between the heavy and extra heavy rates of seeding was not significant.

The "F" value for the interaction between varieties and rates of seeding far exceeded the 1 per cent point of significance. The "F" value for rates of seeding was not significant since the negative and positive correlation for two varieties tended to neutralize each other. Plans for 1941 will include rates of seeding for each variety at several additional planting dates to further study this relationship.

Discussion and Conclusions

The data presented in this paper are preliminary but show that time of planting, rate of seeding, and possibly the interaction between time and rate might influence the yields of the newer varieties of lima beans when compared with Henderson. Likewise, yield trials which do not take these factors into consideration may not be a valid comparison of the yielding ability of lima bean varieties.

Henderson apparently is not influenced greatly by stand of plants; at least, for stands between 5.5 to 11.5 plants per yard. Early Baby Potato appears to require fewer plants per yard, at least for late June plantings, as the lowest rate of seeding (38.9 pounds per acre) with a stand of approximately 5.0 plants per yard, gave the highest yield. Maryland Thick Seeded, a small growing variety, produced its highest yields at the heavy rate of seeding (37.5 pounds per acre) with a stand of 9.0 plants per yard.

Lima beans for canning in Maryland, with a few exceptions, are planted as a succession crop following peas. On the Eastern Shore the harvest dates for Alaska peas varies from May 25th to June 10th, and allowing a short time for land preparation, limas are then planted from the middle of June to almost the middle of July. The data presented indicate that the later the plantings after June 7th the heavier the yield. This was pointed out by Cordner (2) who used 10 dates of

planting of Henderson from May 10th to July 12th. He found that the May plantings out-yielded the June plantings in every case and he suggested that if plantings could not be made in May they should be deferred until July 1st or later. He found that moisture was highly correlated with plant growth and with yield and that the size of plant obtained during the pre-blossom period largely determined the size of the crop. Andrews (1) has pointed out the significance of the root-top ratio and its relationship to moisture uptake and transpiration. If soil moisture is one of the most important factors determining yield, and if medium temperatures and high humidity are contributing factors, the selection of the planting date will be governed by a knowledge of average weather conditions. The data presented in this paper also indicate that the later plantings are more favorable for the newer varieties of lima beans, but the possibility of early frosts and field observations suggest that Baby Potato and Baby Fordhook should not be planted much later than June 20th. The data presented this year offer some very definite leads but further trials under different weather conditions and on soils of different fertility levels are contemplated and should help clarify this question of time of planting and rate of seeding.

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The Effect of Plant Spacing on Yield, Ear Size, and Other Characters in Sweet Corn[1]

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IN THE spring of 1937 a study of plant spacing with sweet corn was undertaken in order to ascertain the optimum planting rate for important varieties used for canning in Maine. Although this problem has been extensively studied in the Corn Belt states for field corn varieties, and more recently for sweet corn, very little work has been reported in New England where the growing conditions and the varieties used are quite different from those existing in the Midwest. A summary of three years' study of this problem is presented in this paper.

Morrow and Hunt (2) in 1888 concluded that yields from field corn were practically the same from drill row and hill planting as long as the number of plants per acre was kept constant. In 1891 Morrow (2) reported that thick planting rates reduced the average ear weight and increased the number of barren plants in field corn. Huelsen (1) has reported similar findings from recent planting rate studies with sweet corn in Illinois. Watson and Davis (4) reported that close spacing gave highest yields but smaller ears in trials conducted in Puerto Rico.

The experimental plots were located in Monmouth, Maine, which is in the commercial sweet corn canning area. A different farm was employed for the work each year and the yield levels for each of the three years, 1937, 1938 and 1939, were decidedly different, thus indicating a different environment each year due to one or more factors concerned with soil, fertility, moisture, and climate. Although there might have been certain advantages in confining the experiment to one soil type in order to study more critically the spacing effect under a given fertility level, the wide range in average yields of the three experimental plots has perhaps demonstrated more vividly the interrelation of growing conditions and spacing on plant performance.

The varieties used in the study comprise two top crosses which are extensively used in the canning industry and were chosen to represent the two fairly distinct types used in the Maine area at the present time. Portcross 100 is a top cross produced by crossing a locally developed strain of Golden Bantam with inbred L100 developed at the Maine Agricultural Experiment Station. This is representative of several hybrids and varieties that are planted to mature the crop during the early part of the canning season. This group is characterized by plants of medium vigor, a tendency to tiller freely and a maturity season that averages approximately a week ahead of the second type. Top Cross Maine Bantam is typical of the late season group of hybrids. The hybrids of this group practically all comprise crosses involving Purdue 1339 as one parent. These are more vege-

[1]The writer wishes to express appreciation to Mr. D. M. Bailey and to Mr. W. B. Ennis for their excellent assistance and to the Maine Canners' Association for valuable aid in providing facilities in connection with this study.

tative than the early group, do not tiller as freely, mature later and generally produce heavier yields. As a basis for comparative vegetative vigor Portcross 100 (P × 100) averaged 67 inches in plant height in the 1940 trials and Top Cross Maine Bantam (TCMB) plants averaged 78 inches.

Outline of Methods

Seed was drilled at the rate of 10 to 12 quarts per acre at planting to insure an excess of plants. Soon after emergence the plots were laid out and thinned to the desired average distance between single plants in the row. At thinning, random plants were removed in order to avoid any bias in the experiment due to removal of inferior plants. Spacing distances of 4, 6, 8, 10, 12 and 14 inches between single plants in the row were employed for Portcross 100 for each of the three years, 1937, 1938 and 1939. Six-, 8-, 10-, 12-, 14-, and 16-inch spacings were chosen for the larger stalked, later maturing Top Cross Maine Bantam in 1937 and 1938. In 1939 an additional treatment was included, a 4-inch spacing for Top Cross Maine Bantam. Rows were planted 3 feet apart each year. To reduce border effect between spacing treatments the plots were arranged systematically end to end in blocks. Between each block a 3-foot border with gradient thinning was employed to avoid the competition of close spacing adjacent to wide spacing.

There were five plots of each treatment for each variety in 1937 and 1938, thus making a total of 60 plots for each of these years. In 1939 there were nine plots for each spacing distance with Portcross 100 and seven with Top Cross Maine Bantam, making a total of 103 plots.

The plot sizes employed were as follows: in 1937 15 rows wide and 14½ feet long; in 1938 12 rows wide and 19 feet in length, and in 1939 seven 20-foot rows. Border rows were provided which were thinned according to spacing in adjacent plots in order to minimize border effect. These were not harvested as part of the experiment.

At harvest, individual plot yields of corn in the husk were recorded. A 50-pound sample from each was used to obtain the data pertaining to "cut off per cent", grade, and ear weight in the husk. Ear length measurements were made on 10 to 25 husked ears taken at random from the 50-pound sample. The number of ears produced per plant was computed by dividing the calculated yield of ears per plot by the number of plants left after thinning.

Discussion of Results

Spacing in Relation to Yield in the Husk:—The relationship of spacing to yield reported in this paper was confined to drill row planting. Huelsen (1) has reported somewhat greater yields from drilling than from planting in hills, but it is doubtful if much difference could be demonstrated in Maine because of the tendency to practice closer planting under both systems than is typical of Midwest conditions. A study of Fig. 1 suggests the following major conclusions:

(a) Soil or climatic conditions, or both, were vastly more important in influencing the yield per acre than were the spacings used in this experiment.

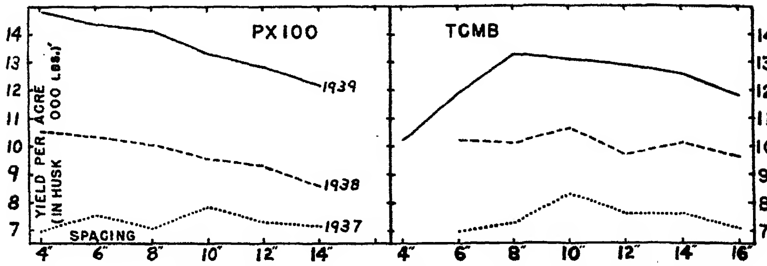

FIG. 1. The effect of plant spacing on yield per acre in the husk; listed in thousands of pounds.

Note: P × 100 = Portcross 100, TCMB = Top Cross Maine Bantam.

(b) The optimum spacing distance in the drill row for both varieties varied, depending upon the yield level prevailing for each year. In general, the better the growing conditions the smaller the amount of feeding area that was required for the plant to develop its crop efficiently. The yield per acre is dependent upon both the efficiency of the individual plants and the number of plants feeding on the area, hence a too great reduction in either reduces yield.

(c) The later maturing, more vegetative Top Cross Maine Bantam required somewhat greater feeding area for the most practical plant development than did Portcross 100.

(d) The decrease in yield with widest spacing distances was surprisingly low in view of the numerical reduction in the total plants per acre.

Effect of Spacing on Per Cent of Usable Ears:—A large part of the Maine sweet corn crop is purchased on the basis of per cent of usable ears. This term is used to express the per cent of the 50-pound unhusked sample that is represented by the weight of the sample after husking and the removal of culls. An examination of the data presented in Table I shows that with the close spacing of 4 inches, the per cent of usable ears was considerably lower than with the intermediate spacings. This was probably due to the inclusion of many nubbin ears at harvest. It is also interesting to note that there was also a general tendency for the per cent of usable ears from the extreme wide spacings to be lower. The reason for this certainly is not due to severe plant competition, but is likely because of many small second and possibly to tertiary ears produced by the plants. This assumption is borne out

TABLE I—PER CENT OF USABLE EARS WITH DIFFERENT SPACINGS

Spacing	Portcross 100		Top Cross Maine Bantam	
	1938 (Per Cent)	1939 (Per Cent)	1938 (Per Cent)	1939 (Per Cent)
4	66.4	67.1	—	68.7
6	69.0	70.4	70.0	72.0
8	69.0	69.9	71.4	71.0
10	69.4	70.7	69.2	69.0
12	68.4	68.4	68.2	68.0
14	67.8	68.4	66.4	68.7
16	—	—	64.8	69.7

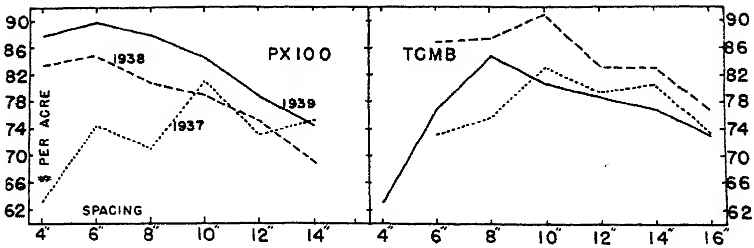

FIG. 2. Effect of spacing on dollars return per acre.
Note: P × 100 = Portcross 100, TCMB = Top Cross Maine Bantam.

by the data taken on the number of ears per plant, ear length, and the number of ears required to make a 50-pound sample, see Figs. 3, 4, and 5. Any trend in the intermediate spacing is not clearly evident. Possibly further critical analysis of the data by statistical treatment will clarify this point.

The Effect of Spacing on Cash Returns Per Acre:—In Fig. 2 is plotted the dollars return per acre in relation to spacing. Because the value of the raw product per acre at a given price is dependent upon both yield and the per cent usable, the value to the farmer was not directly proportional to the yield in the husk. A different base price was paid by the canning companies during each of the three years and because of this the value per acre was not directly proportional to the differing yield levels prevailing each year.

The Effect of Spacing on Maturity:—The data which have been taken to clarify this point have not been entirely satisfactory. Milk test records have been too variable to show definite trends. Data of silking records from the various plots clearly show that on a given date the per cent of plants in silk was progressively greater with wider spacing. These data cannot be considered a reliable index of relative maturity since a study of Fig. 3, shows that with close distance many of the plants were barren at harvest time. Thus, perhaps many of the

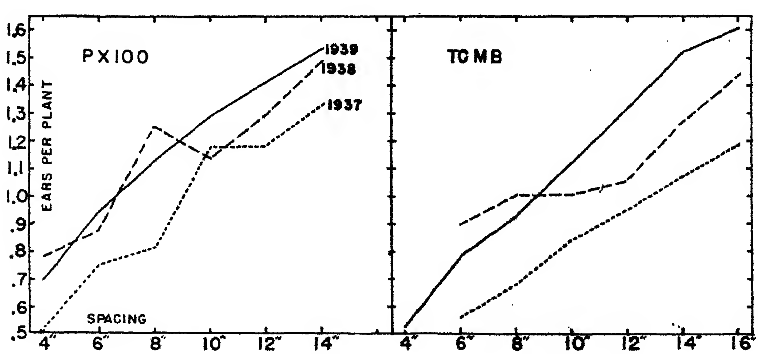

FIG. 3. The effect of spacing on the average number of ears produced per plant.
Note: P × 100 = Portcross 100, TCMB = Top Cross Maine Bantam.

plants which had not silked on the date of observation never did, or emergence was only after competition and growing conditions precluded all chances for ear development. General observations and study of the silking and milk test data appear to justify the statement that very close spacing delays maturity one or two days under average conditions.

Effect of Spacing on Number of Tillers:—The results of studies by Huelsen (1) indicate that as the spacing distance is increased the number of tillers per plant also increases. This is in agreement with data collected in Maine in 1938 with three varieties which were in trial that year. In Table II is listed on a percentage basis the number of stalks (4 feet tall or above) present at harvest time compared to the count at thinning. In Table II it will be observed that in cases of the close spacings the percentage figure is less than 100. This was due to loss of plants from various causes after thinning. Had there been no plant mortality or tiller development in the closest spacing the percentage figure would have been 100. It seems reasonable to assume that the mortality loss in per cent would have been nearly the same for all treatments. Thus, the increase in per cent of plants at harvest above that of the closest spacing can be attributed to increased tiller development as plant distances were increased. The marked increase in the percentage figure for the 8-inch spacing is difficult to explain but may have been due to the location of these plots.

Spacing Distance in Relation to Barren Plants and Number of Ears per Plant:—A study of Fig. 3, shows the marked increase in the average number of ears produced per plant as spacing was increased. The values were obtained by dividing the calculated number of ears harvested per plot by the number of plants left at thinning. It is obvious that there were many barren plants with close spacing, since the number of ears produced averaged less than one. The question may arise as to whether the increase in the average number of ears per plant above one was due to additional ears produced on the main stalk or to yield from tiller plants. In 1939 the percentage of two eared plants (based on count at thinning) was determined by field count in the Top Cross Maine Bantam plots and these are shown in Table III.

TABLE II—THE EFFECT OF SPACING ON INCREASING THE STALK COUNT AT HARVEST (1938 DATA AND LISTED AS PER CENT OF PLANTS LEFT AT THINNING)

Spacing (Inches)	Variety and Per Cent		
	Portcross 100	Top Cross Maine Bantam	Golden Bantam
4	89	—	—
6	90	76	89
8	119	93	112
10	110	88	107
12	113	90	103
14	125	100	110
16	—	104	121
Minimum difference necessary for significance, 5 per cent.*	12.3	10.2	15.0

*(Fisher's Analysis of Variance)

TABLE III—Spacing and Per Cent of Plants Producing Two Ears and Average Number of Ears per Plant in Top Cross Maine Bantam (1939)

Spacing (Inches)	Per Cent Stalks With Two Ears	Average Number of Ears Per Plant (See Fig. 3)
4	0.0	0.5
6	0.4	0.8
8	2.6	0.9
10	7.3	1.1
12	16.8	1.3
14	27.8	1.5
16	31.6	1.6

A study of Table III reveals that at least in this variety the increase above the average of one ear per plant was in a large measure due to second ears on the main stalk. It would seem that the above data can be explained as follows: One hundred plants in the 4-inch spacing plots were found to yield 50 ears. There were no two eared plants, hence one-half the plants were barren. It is clear that even with the 8-inch spacing the increase due to 2.6 per cent of the plants producing two ears was not quite sufficient to balance the barren plants because there was produced on the average 0.9 ear per plant. At 10 inches 100 plants bore approximately 110 ears. If it can be assumed that at this distance nearly every plant produced at least one ear, then 107 ears would be the expected yield with 7 per cent of the plants bearing two ears. For the 12-, 14- and 16-inch spacings the theoretical yield of 100 plants would be approximately 117, 128, and 132 ears, respectively. Actually the yields were found to be 130, 150 and 160 based on the data taken from Fig. 3. Thus, it would appear that about one-half the increase above one ear per plant could be attributed to two eared stalks; the other half to tiller plants.

The Effect of Spacing on Ear Length and Weight:—Fig. 4, needs a little discussion. The average lengths of the ears measured each year varied considerably, perhaps due to the technique followed. In 1937 10 random ears from each plot were hand husked and measured. In 1938 and 1939 the samples were increased to between 15 and 25 random ears from each plot and these were measured after passing through a machine husker. The butting mechanism removed some of

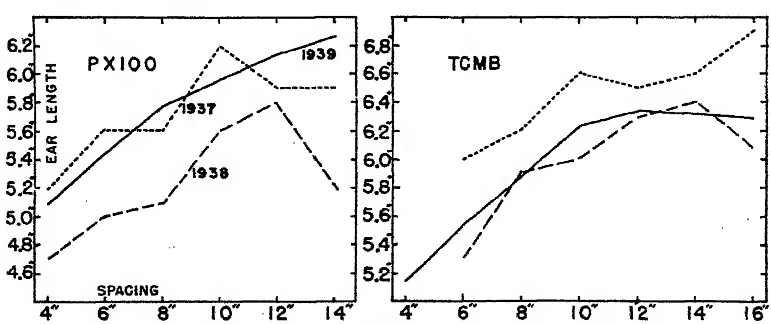

Fig. 4. The effect of plant spacing on average ear length.

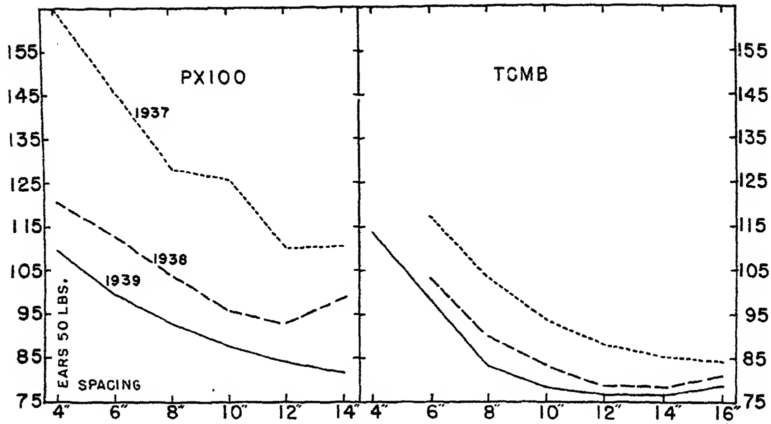

FIG. 5. The relation of spacing to the number of ears required to make a 50-pound sample.
Note: P × 100 = Portcross 100, TCMB = Top Cross Maine Bantam.

the basal kernels and the adjustment may not have been the same both years. These factors, however, were not considered to seriously interfere in the study of ear length increases in relation to different spacings. It should be noted that a marked increase in ear length occurs when plant distance is increased even to at least the 12-inch spacing. The trend of the curves in Figs. 4 and 5 at the very widest spacings suggest that in some cases there may be a reduction in average length and weight, probably due to the increased numbers of smaller secondary ears. It will be recalled that the lower percentages of usable ears with the widest spacings also support this belief.

Fig. 5 shows the relation of spacing to the number of unhusked ears required to make a 50-pound sample. As would be expected these curves are more or less the inverse of those shown in Fig. 4, but the plottings follow smoother curves because of the large number of ears counted from each plot. It is interesting to note the direct relationship between the yield levels of each year and ear size,— the greater the general yield the greater was the average ear weight.

Summary of Results

A summary of the findings in this planting rate study indicates that:

1. The earlier maturing, less vegetative Portcross 100 required less feeding area for optimum development than did Top Cross Maine Bantam.

2. There is some tendency, within certain limits, for the higher per cent of usable ears to offset the loss in yield in the husk with increased plant spacing. Both the per cent of usable ears and the yield in the husk were lower from extreme wide spacings of 14 and 16 inches.

3. Soil or climatic conditions or their interaction had more influence on the yield than did the spacings used in this experiment. Six inches

to 1 foot between plants planted in drill row, depending somewhat on the variety used, appears to be the most practical range to recommend for most Maine conditions.

4. Close spacing delayed maturity 1 or 2 days.

5. As the plant feeding area was increased there was a marked tendency for the plant to produce more ears, heavier and longer ears, and more tillers. Close spacing caused many barren plants. Extreme spacing permitted the development of smaller secondary ears, which reduced the average ear weight, length and the per cent of usable ears.

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The Effect of Methods of Growing and Transplanting the Plants on the Yield of Peppers[1]

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THE pepper is not a frost hardy plant and it requires a relatively long growing season to produce a profitable yield. In order to lengthen the growing season in the North, the seed is usually sown in greenhouses or other forcing structures during late winter or very early spring. It is also desirable to grow large, thrifty plants to transplant in the field because early peppers command the highest prices. There are several methods and many variations of each method for growing early plants to be transplanted and it is the purpose of this paper to report three years' results of growing and transplanting pepper plants in various ways.

Seeds were sown thinly in flats during the second week in March and the seedlings pricked out about 3 weeks later and planted or treated in the various ways outlined below. All plants which were grown in flats after being pricked out were spaced 3 by 3 inches. The dimensions of the flats were 20 by 12 by 3 inches. The variety, Waltham Beauty, was used throughout the tests and the soil was a Merrimac fine sandy loam with a pH of 6.0 and in a high state of fertility. A 5–8–7 fertilizer was applied broadcast to the soil at the rate of 1,500 pounds to the acre. The plants in each test were planted 18 inches apart in rows 3 feet apart. Frequent shallow cultivation was given to the plantings each season. The fruits were harvested when it was felt that they had reached their full size but before they had taken on any red color.

Five treatments were used in the preliminary tests conducted during 1938, and are described as follows: 1, Plants grown in four-inch clay pots; 2, plants grown in flats with an application of 8 grams of dextrose per flat; 3, plants grown in flats with 18 grams of 16 per cent superphosphate plus the basic application of dextrose; 4, plants with the dextrose and superphosphate treatment plus artificial light. This consisted of light from a 200-watt Mazda bulb with a reflector suspended 36 inches from the plants. The light supplemented daylight from 4 p.m. until 11 p.m.; and 5, plants given the basic application of superphosphate and blocked out 10 days previous to setting in the field. This particular lot of plants also received 1 pint of transplanting solution per plant as suggested by Hester (3, 4). The plants were set in the field on June 1 and each treatment replicated five times in the form of a Latin square. Each replication consisted of 15 plants.

In 1939 the following eight treatments were used: 1, Plants grown in 3-inch clay pots; 2, plants grown in flats and blocked 10 days previous to field planting; 3, plants grown in flats without additional treatment; 4, plants grown in flats with ½ pint of transplanting solution applied at the time of setting in the field as suggested by Sayre (10);

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5, plants grown in 3-inch clay pots with Sayre's transplanting solution added; 6, plants grown in 3-inch paper pots; 7, plants grown in 3-inch paper bands; and 8, plants grown in a poor soil on a sash house bench. The plants were set in the field on June 2 and the treatments replicated eight times in the form of a Latin square. Each replication consisted of 10 plants.

The treatments in 1940 were similar to those in 1939 except that the lot of plants grown in poor soil (treatment 8) was replaced by plants grown in 3-inch paper pots and watered with ½ pint of Sayre's transplanting solution at planting time. The plants were set in the field on June 7 and the treatments replicated eight times in a Latin square.

The data were subjected to Fisher's analysis of variance (9) and a difference was considered significant when the odds were 21 to 1 that it was not due to chance. Table I contains a summary of the 1938 experiments together with the averages of the plot yields and the difference between yields which is necessary for significance.

TABLE I—Response to Treatments in 1938

Treatments	Early Yield (Ozs)	Total Yield (Ozs)
Clay pots	101.4	176.0
Dextrose	31.4	113.4
Dextrose plus P_2O_5	39.2	130.4
Dextrose plus P_2O_5 plus artificial light	41.6	112.6
P_2O_5 plus blocked plus transplanting solution	45.8	116.8
Difference necessary for significance between two treatments	11.5	37.6

The fruit harvested in the first three pickings is designated as the early yield. Treatment 1, plants grown in 4-inch pots, produced more than twice as great an early yield as any of the other treatments. This treatment also proved to be significantly better than the others in total yield. The noteworthy benefits of growing plants in clay pots have been emphasized by a number of investigators (2, 5, 6, 7). Lengthening of the photoperiod did not appear to be especially beneficial. This is in line with the findings of Cochran (1). Additions of phosphorus and dextrose produced little in the way of significant results in these experiments.

In Table II are included the data and analysis of the 1939 and 1940 experiments. The differences displayed in the results probably are due to the abnormal growing season encountered in 1940. In both years the plants grown in clay pots with transplanting solution added produced a greater early yield than any of the other treatments, although this difference was not significant in all cases.

It is evident, however, that well-grown plants are necessary to secure large early yields. Treatment 8 in 1939 produced a very low total yield and nothing was harvested from these plants during the early harvest period. The plants grown in paper pots suffered from nitrogen shortage during 1940. Applications of a weak solution of nitrate of soda appeared to correct the deficiency and these plants were among the highest yielders. This was to be expected on the basis of the findings of Knott and Jeffries (6). It did not appear that the weight of individual

TABLE II—Response to Treatments in 1939 and 1940

Treatments	1939 Early Yield (Ozs)	1939 Total Yield (Ozs)	1940 Early Yield (Ozs)	1940 Total Yield (Ozs)
Clay pots	40.75	189.00	91.50	264.25
Blocked	27.75	143.88	93.00	301.63
Flat grown	38.13	168.63	48.63	221.25
Transplanting solution	44.13	185.25	83.13	235.25
Clay pots plus transplanting solution	44.63	203.50	104.13	289.13
Paper pots	12.50	164.13	85.50	263.63
Paper bands	31.13	146.00	62.63	218.50
Poor soil	00.00	109.88	——	——
Paper pots plus transplanting solution	——	——	80.75	281.63
Difference necessary for significance between two treatments	14.42	31.28	17.65	47.03

fruits was any greater on plots with high yields than on plots with low yields.

There was a tendency for the differences due to treatment to disappear as the season advanced. Loomis (8) has explained this in part as the gradual recovery of the plant from the shock of transplanting. It appears that any method which will produce a large, well-grown plant will assure large early yields if the plant can be transplanted in the field without much injury to the root system.

The addition of transplanting solutions in most cases increased the yield over the basic treatment even though a marked response is not usually expected on a fertile soil. Transplanting solutions appeared to be quite effective in encouraging a quick replacement of roots and in stimulating early plant growth.

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Growth of the Perfection Pimiento Fruit

By H. L. Cochran, *Georgia Agricultural Experiment Station, Experiment, Ga.*

FRUIT size is of economic importance in the Perfection pimiento. Therefore, growth-rate studies of the fruit were started at the Georgia Agricultural Experiment Station in 1938 with the hope of throwing some additional light on this problem. Little published work on the sizing of fruits was to be found in the literature prior to that reported on squash by Anderson (4) in 1895. Since that time, however, numerous investigators, notably pomologists, have turned their attention to the subject for the most part using fruits belonging to the genus Prunus in their work: Albert and Hilgeman (1); Aldrich and Work 2; Aldrich and Crawford (3); Blake (5); Connors (8); Cullinan and Weinberger (9); Dorsey and McMunn (10, 11, 12); Farley (13); Jones (16, 17); Lott (25, 26); Lott and Ashley (27); Lilleland (19, 20, 21); Lilleland and Newsom (23); Lilleland and Brown (24); McMunn (28); Tukey (31, 32, 33, 34, 35); Verner (37); Weinberger (38); and Weinberger and Cullinan (39). Gustafson (14) has reported results of growth studies on fruits of the summer squash, cucumber, muskmelon, and tomato, as has Smith (30) on potato tubers. Results of similar studies on pecan and almond nuts have been reported by Van Horn (36) and Brooks (6) respectively.

Materials and Methods

These studies were conducted in the field of Mr. F. J. Summers near Experiment, Georgia, during the 1938 growing season and in the horticultural greenhouse at the Georgia Agricultural Experiment Station during the winter of 1938–39. Five young buds each measuring 5 millimeters in diameter were selected and tagged on each of 50 uniform plants growing in the field on August 15. Five like buds were tagged on each of 28 plants growing in the greenhouse on December 21. Diameter measurements were made with a Vernier caliper, the reading being taken at the nearest .5 millimeter, at weekly intervals, and a separate record was kept of the growth of each fruit until it matured, the standard of which was a deep red color, or until it dropped. Because of the relatively high percentage of fruit set, no substitutions were made for those that abscissed. Samples were taken each week for fresh and dry weight determinations of other field-grown fruits having a diameter equal to that of the average of all fruits measured for that week. The material for drying was sliced thinly and dried for 72 hours at 60 degrees C in a forced-draft electric drying oven.

Experimental Results

Diameter Measurements:—The seasonal growth curves based on measurements made at weekly intervals of fruits growing in both the field and greenhouse are presented graphically in Fig. 1. These curves are also typical of the growth of single fruits.

During the two-week period that elapsed between the date on which

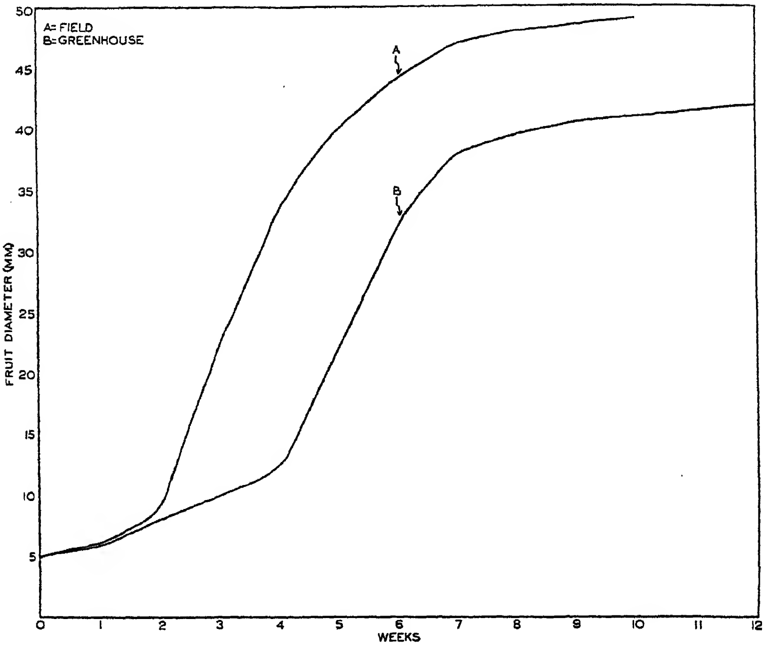

FIG. 1. Growth of the pimiento fruit as measured by increases in diameter when grown under (A) field conditions, (B) greenhouse conditions.

the measurements were started on field-grown fruits and anthesis the young buds increased in size at the average rate of 0.29 millimeters per day and at the end of this period had attained an average diameter of 9 millimeters. Practically all buds were in full bloom on the 13th day after the outset of the experiment. Several subsequent daily examinations after this particular period showed that the ovaries started making appreciable gains in diameter within 3 or 4 days. Although no histological examinations were made of the young ovaries in this study similar work conducted previously by Cochran (7) on those from greenhouse-grown plants would tend to substantiate the statement that this sudden increase in ovary size was due to fertilization. The stimulating effects of gametic union, as shown by the gradient of curve A in Fig. 1 was most pronounced during the third and fourth weeks. In fact, within this time the fruits increased in diameter at the rate of 1.0 millimeter per day, the rate of which was approximately three and one-half times as rapid as that made by the same young ovaries during a like period prior to fertilization. These findings are well in accord with those of Murneek (29) who reported for tomatoes that with a union of gametes growth was stimulated especially in the tissues surrounding the embryos. Results of controlled pollination experiments in the tomato as reported by Judkins (18) also show a very definite increase in fruit diameter as the result of fertilization.

After the fourth week the fruits exhibited a decrease in growth rate which gradually became less as maturity approached. The first evidence of fruit ripening, as shown by a definite change in exterior color from dark green to brown, was observed at the end of the eighth week. By the end of the tenth week all fruits were ripe and ready to be picked.

In the case of greenhouse-grown fruits the increase in diameter was somewhat slower than in those produced under field conditions as can be seen in curve B of Fig. 1. The buds were 24 days coming into full bloom and gained in diameter at the rate of only 0.25 millimeters per day up to this time. Within 4 days after this, however, or by the end of the fourth week, fertilization had apparently taken place as was indicated by the same abrupt increase in growth rate noted in field-grown fruits. During the fifth and sixth weeks the fruits increased in growth quite rapidly and by the end of this time had reached a diameter of 32 millimeters. From this point until maturity, which was 6 weeks later, the increase was very slow, averaging only 1.7 millimeters per week. No signs of red color appeared on the fruits until the ninth week, after which it took them three weeks to fully ripen. The length of time required for the fruits to mature in the greenhouse was 12 weeks and their average diameter at harvest time was 42 millimeters.

Fresh and Dry Weights of Field-Grown Fruits:—The seasonal rate of fruit growth as determined by fresh and dry weight at definite intervals is shown in Fig. 2. The fresh weight curve, Fig. 2, A is S-shaped, thus corresponding in general to that obtained by diameter measurements under field conditions. The rather slow increase for

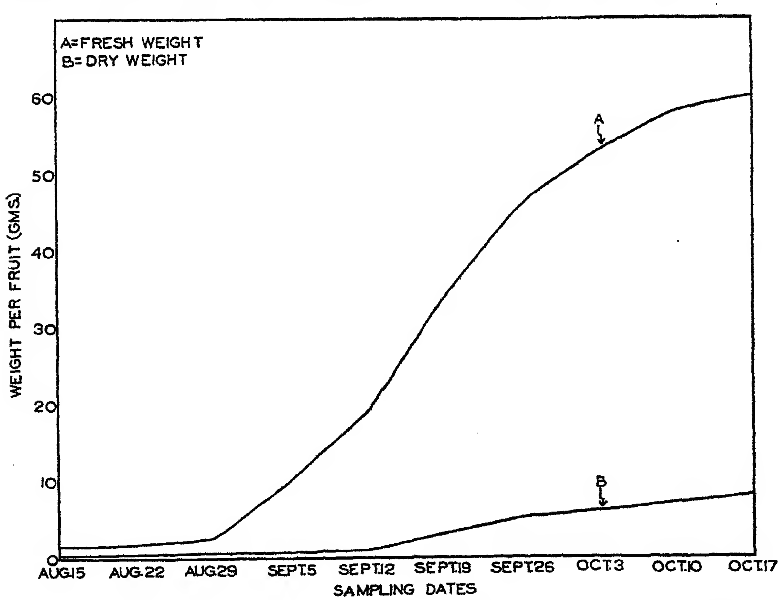

FIG. 2. Growth of the pimiento fruit under field conditions as measured by increases in (A) fresh weight, (B) dry weight.

the first 2 weeks, prior to fertilization, was followed by a rapid rate, which tended to drop off as fruit maturity approached. The final average fresh weight of the fruits was 60 grams.

The dry weight per fruit curve, Fig. 2, B follows much the same course as does that for fresh weight. However, due to the rather large gram increments on the abscissa, the S-shape of the curve is not very apparent. Dry weight increased a great deal faster after the first week in September than it did during the last 2 weeks in August. It reached its maximum acceleration rate on September 26 from which point it gradually decreased as the season ensued. The average dry weight per fruit at harvest time was 8 grams.

Discussion

From data secured in this work, it seems feasible to divide the size increase of the Perfection pimiento fruit into the following stages:

Stage 1. A period of slow growth which lasts from the early bud stage until 3 or 4 days after full bloom.

Stage 2. At this point a period of rapid growth starts, the duration of which is approximately 3 weeks.

Stage 3. The rapid growth rate of stage 2 suddenly slows down and gradually decreases as maturity approaches.

When these rates of growth are plotted graphically against time, an S-shape curve, although not normal in every respect, is obtained. It was of special interest in reviewing the literature to find that these growth stages and the resultant sigmoid curves were practically the same for most all types of fruits that have been studied except those of the genus Prunus. In these cases the size increase is also periodic. The first stage is one of very rapid development which slows down in mid-season for the second stage, and finally breaks into a very rapid increase, similar to stage 1, for the third.

Although the young buds in the field and greenhouse were the same size when measurements were started, those growing outdoors were 2 weeks earlier coming into full bloom and the fruits ripened 2 weeks earlier than those in the greenhouse. These differences were perhaps due to a number of contributing factors, chief among which were light intensity, temperature, and nutrition. These same factors no doubt account in part for some of the discrepancies in the curves of this work. In fact, Gustafson (15) points out that nutrition alone has a very great effect on the growth curve of fruits. He is of the opinion that poorly developed conductive systems in fruits may very materially limit the nutrients supplied to these fruits. Lilleland (22) working with the apricot fruit under controlled temperatures was able to mature and ripen fruits 28 days earlier under these conditions than like ones growing under ordinary outdoor conditions.

Summary

The S-shape growth curve was obtained in this study for the Perfection pimiento fruit over the period lasting from the early bud stage to maturity. The growth of the fruit is divided into three well defined

periods. A period of rather slow growth is followed by one of rapid growth rate which tends to decrease as maturity approaches.

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Measurement of Solids in Melon Juice

By H. W. ALLINGER, C. S. BISSON,[1] E. B. ROESSLER, and JOHN H. MACGILLIVRAY, *University of California, Davis, Calif.*

THE field or hand refractometer is a convenient means of measuring the sugar content of melons even though the juice is not all sugar. As Scott and MacGillivray (5) have pointed out, an instrument standardized for one solution may not be used indiscriminately for all solutions. This paper discusses the magnitude of the differences involved in the use of this instrument as well as of the Abbé refractometer, and gives the composition of solutes found in melon juice.

METHODS

The field refractometer used had a scale of 0–30 per cent for measuring dry substance or sucrose and was adjusted to read correctly at laboratory temperatures. The Abbé refractometer was used to measure the index of refraction which was converted to per cent sucrose by means of Schonrock's Table (4). The per cent total solids was determined by evaporating the juice almost to dryness on a steam bath and then drying the residue for 6 hours at 70 degrees C *in vacuo*. The organic and inorganic constituents were determined by standard methods. In two comparisons made with cantaloupes, sucrose inverted by hydrochloric acid gave a reading 0.02 per cent lower than sucrose

TABLE I—RELATION OF TOTAL SOLIDS READINGS BY THREE DIFFERENT METHODS (FRESH WEIGHT BASIS)

Variety	Year	Number of Fruits	Per Cent Solids From: Refractometer Reading Abbé* A	Per Cent Solids From: Refractometer Reading Field B	Per Cent Solids From: Drying 70 Degrees C in Vacuo C	Per Cent Sugar Reducing	Per Cent Sugar Total	Significance of Comparisons† A-B	B-C	A-C
				Davis						
Cantaloupes Various	1937	12	12.8	12.2	11.8	2.53	9.32	S	S	S
Honeydew		10	14.5	13.9	13.5	3.45	11.53	S	S	S
Casaba		10	13.2	12.1	11.9	2.91	9.99	S	S	S
Persian		10	12.4	12.2	11.9	3.25	9.81	S	S	S
P.M.R.No.45	1938	11	13.6	12.4	11.8	1.90	9.42	S	S	S
Tip Top		9	8.6	7.5	7.1	3.10	5.71	S	S	S
Honeydew		10	14.8	13.9	13.4	2.98	11.66	S	S	S
Casaba		10	12.8	12.1	12.1	1.99	10.36	S	NS	S
Persian		11	13.2	12.4	11.9	2.58	10.00	S	S	S
				Keyes						
Watermelon	1939	7	10.8	10.6	10.4	5.71	9.00	NS	NS	S
	1940	12	10.7	10.3	10.2	4.77	9.12	S	NS	S
				Davis						
Watermelon	1939	8	11.4	12.0	11.3	4.86	9.74	S	S	NS
	1940	12	11.6	11.2	11.1	5.56	10.40	S	NS	S

*Refractive Index converted to per cent sucrose by Schonrock's Table (4).
†S =significant, NS =not significant.

[1]This manuscript was prepared after the death of Dr. Bisson.

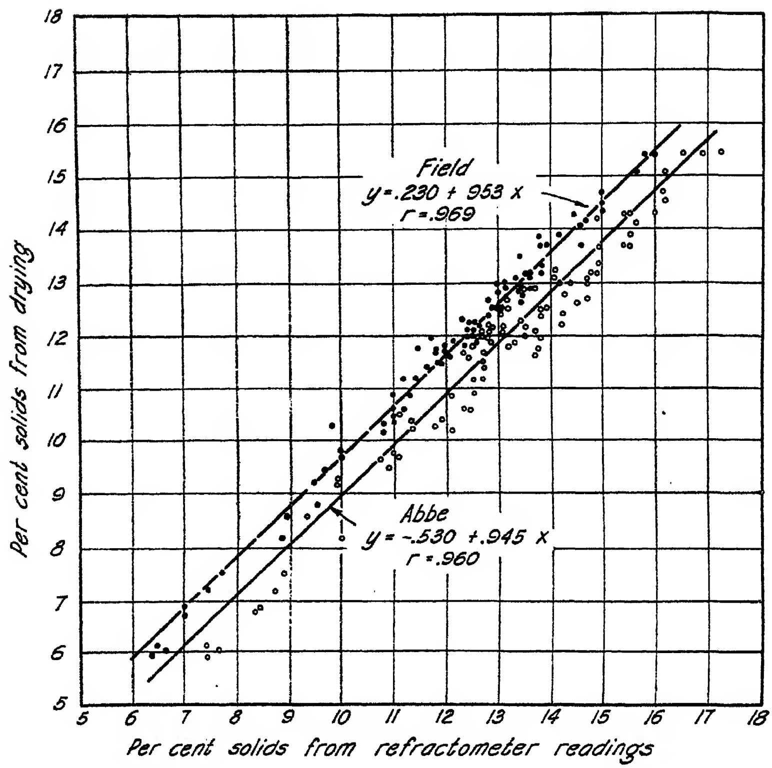

FIG. 1. Regression lines for per cent solids by drying and solids from field or Abbé refractometer readings for *Cucumis melo*.

inverted by invertase. The juice was pressed from the edible flesh (5), and all comparisons were made on juice from the same melon. "Student's" (3) method was used to determine significance.

RESULTS AND DISCUSSION

The data presented in Table I and Figs. 1 and 2 indicate the high degree of correlation existing between the results of the three methods; evidently, any of them may be used to measure soluble solids, though with slightly differing accuracy. The greatest value obtained is secured by converting the Abbé reading to sucrose by means of Schonrock's Table. The determination of solids by drying gives the lowest, and the field refractometer reading is intermediate. Almost all the comparisons for *Cucumis melo* and over two-thirds of the comparisons for watermelons give significant differences. The three methods tend to check more closely for watermelons, perhaps because a higher percentage of the soluble solids are sugars. The average field refractometer readings for each type of melon were 3.3 per cent higher than the results by drying, and the average Abbé readings were 10.4 per cent higher than

the results by drying for *C. melo*. For watermelons the results secured by the Abbé reading were similarly 2.5 per cent and 3.5 per cent higher than the results obtained by drying. The results found in Tables II and III eliminate potassium salts as one possible explanation for these variations.

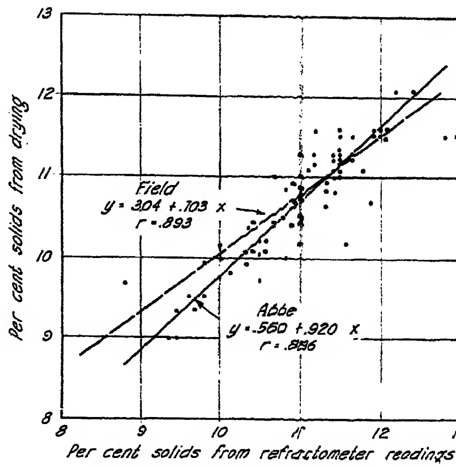

FIG. 2. Regression lines for per cent solids by drying and solids from field or Abbé refractometer readings for watermelons.

Nitrogen and ash analyses are found in Table II. Watermelons are distinctly lower in ash and slightly lower in nitrogen when compared with the *Cucumis melo* varieties used. Watermelons seem lower in most of the elements determined except magnesium. Potassium is the high constituent, forming more than one-third of the ash in all melons.

TABLE II—PARTIAL ANALYSIS OF JUICE FROM MELONS (FRESH WEIGHT BASIS)

Variety	Year	Number of Fruits	Per Cent Ash	Ca	Mg	P	K	N
		Davis						
P.M.R. No. 45	1938	11	0.77	.006	.005	.028	.35	.18
Tip Top	1938	9	0.64	.007	.005	.026	.25	.07
Honeydew	1938	10	0.87	.005	.004	.020	.37	.14
Casaba	1938	10	0.75	.005	.003	.011	.32	.12
Persian	1938	11	0.78	.007	.004	.015	.34	.14
		Merced						
Watermelons	1939	7	0.32	.003	.008	.016	—	—
	1940	12	0.36	.004	.010	.022	.16	.08
		Davis						
Watermelons	1939	10	0.38	.003	.006	.014	—	—
	1940	12	0.29	.004	.012	.017	.13	.09

Watermelons were analyzed for per cent chloride, sulfur, and sodium. Chloride averaged .004 per cent, sulfur .005 per cent, and sodium .003 per cent.

Table III is the result of an attempt to learn whether sugar solutions and potassium salts, alone or combined, may account for the differences obtained by the three methods. These differences are not great enough to indicate that this is a justifiable explanation. The one-tenth per cent reduction found by means of the field refractometer is the approximate error of the instrument. Consequently no satisfactory explanation is offered for the differences found by the three methods. Perhaps other

substances occurring in the juice but not determined may cause these differences.

Since the results obtained by drying are the lowest, it seems desirable to consider the accuracy of this method. The procedure followed resembled the official method for drying tomato pulp (4). This method, as well as specific gravity measurements, has been employed in formulating a table for the solids content of tomato pulp (2). This table has been used for 20 years in the commercial purchase and sale of tomato pulp. Further evidence of the accuracy of this method was the degree variation between duplicate samples that were dried. When the juice from each type of melon was dried in duplicate to determine the variation, duplicates were so close that this procedure was not continued for subsequent samples. The average variation between duplicates of 19 samples was .02 per cent solids; the extreme variation, .06 per cent solids. These differences were so small that it did not seem necessary to attempt determining the water in the sample (1).

Lines of regression as shown in Figs. 1 and 2 may be used to change the per cent solids as determined by one method to those of the other methods.

TABLE III—Comparison of Solids by Drying, Field Refractometer, and Abbé Refractometer on Organic and Inorganic Substances

Substance in Water	Per Cent Solids		
	By Weight	Field Refractometer	Abbé Reading Converted to Sucrose by Schonrock's Table
K_2HPO_4	0.53	0.4	0.5
Sucrose	10.0	9.9	10.0
Sucrose }	10.0		
K_2HPO_4 }	0.53	10.4	10.5

Similar results were obtained with potassium sulfate, dextrose, and sucrose with potassium sulfate.

Summary

There are significant differences in the soluble solids readings obtained by drying, field and Abbé refractometers. These differences are small but consistent. The organic and inorganic constituents determined apparently are not a satisfactory reason for these differences.

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The "Difference" Method for Starch Determination of Sweetpotatoes[1]

By J. M. Lutz and Geo. P. Hoffmann, *U. S. Department of Agriculture, Meridian, Miss.* and W. S. Anderson, *Mississippi Agricultural Experiment Station, State College, Miss.*

DEVELOPMENT of the sweetpotato starch industry necessitates use of a rapid, reliable method for determining the starch content of sweetpotato roots in experimental work on the effect of variety, cultural treatments, and storage methods on such starch content.

Kimbrough (1) has found that starch-plus-water content of freshly dug sweetpotatoes is generally around 90 to 91 per cent. From this value it is possible to estimate the starch content by subtracting the moisture content. As Kimbrough has pointed out, this method is applicable only to sweetpotatoes freshly dug before vines have been killed by frost, because of conversion of starch to sugar in sweetpotatoes after the root is separated from the growing top either by harvesting or frost. This method is, of course, only an estimate since Kimbrough's data show there may be a variation of 3-½ per cent between minimum and maximum starch-plus-moisture values. For many purposes, however, this method is satisfactory.

For more precise readings, or for sweetpotatoes that have been in storage, a true starch determination appears to be preferable. Successful use has been made at the Laurel, Mississippi, starch plant of a polariscopic method after conversion by standard amylase,[2] and more recently of Balch's sodium hypochlorite polariscopic method (2). The authors have found the latter very satisfactory for analysis of fresh samples, as well as for samples of mature sweetpotatoes preserved in cold alcohol.

Where a polariscope is not available and a short, fairly accurate method is desired, the "difference" method is suggested. It is nearly as rapid as the polariscopic method—one experienced person can run 15 to 20 sweetpotato samples a day. This method has been used in the corn starch industry for a number of years and was modified for three types of sweetpotato samples as follows:

1. *On Freshly Cut or Rasped Sample:*—The sample is finely prepared with a beet sampling rasp. Dry weight is determined by drying 24 hours at 90 degrees C. The non-starch residue is determined on 5-gram samples as follows: The sample is transferred to an acid-hard-

[1]This study represents one phase of cooperative investigations by the Mississippi Agricultural Experiment Station and the Bureaus of Plant Industry and of Agricultural Chemistry and Engineering. The authors are indebted to Dr. F. H. Thurber, Mr. R. T. Balch, and Mr. R. M. Kingsbury of the Carbohydate Research Division, Bureau of Agricultural Chemistry and Engineering, for suggestions regarding preparation and analysis of sweetpotato samples by polariscopic methods; also, to Mr. W. R. Richee, Manager, Laurel Starch Plant, Laurel, Mississippi, for suggestions and help with the "difference" method. Analyses of a number of samples by the polariscopic amylase method were made for the authors by Dr. Thurber.

[2]Unpublished method by R. M. Kingsbury, Bureau Agricultural Chemistry and Engineering, U. S. Dept. Agric.

ened filter paper on a Buchner funnel with 95 per cent ethyl alcohol. It is then washed once with alcohol and three times with cold water so that the total alcohol and water washings are 200 to 225 cubic centimeters. The filtrate is then made up to 250 cubic centimeters volume and solubles determined on a 50 cubic centimeter aliquot by drying at 90 degrees. The residue on the filter paper is transferred with approximately 125 cubic centimeters of hot water to a 250 cubic centimeters beaker and gently boiled for 15 minutes to gelatinize the starch. It is then cooled to 55 degrees C or lower, and 10 cubic centimeters of malt diastase solution[3] is added, and is then placed in a water bath at 55 degrees C for 1 hour. It is then brought to a boil and filtered while hot on a previously dried and weighed filter paper on a Buchner funnel with suction and then washed three times with hot water. The use of coarse alundum filtering crucibles (RA98) instead of filter paper at this point saves one weighing. Filtration and washing are facilitated by the use of water near the boiling point. The filter paper and residue are dried at 90 degrees C and then weighed in a closed container. The per cent starch (fresh weight basis) equals per cent dry weight minus per cent of solubles and of non-starch residue on filter paper.

As shown in Table I, starch values obtained in this manner on freshly harvested roots were found to be essentially the same as those obtained by the sodium hypochlorite polariscopic method.

TABLE I—Comparison of Starch Values Obtained by Difference and by Polariscopic Method

Date	Variety	Per Cent Starch (Fresh Weight Basis)	
		Polariscopic Method	Difference Method
Nov 22, 1939	Triumph	21.80	22.10
Feb 20, 1940	Porto Rico	15.81	15.58
Feb 20, 1940	Triumph	21.97	22.18
Jul 12, 1940	Triumph	22.75	22.75
Aug 23, 1940	Triumph	24.94	25.18
Aug 23, 1940	Porto Rico	21.17	21.75

In order to determine the variability that could be expected of replicate analyses from the same lot of material, five separate analyses were made on three lots of material by each of the two methods. The coefficients of variability (standard deviations in per cent of the mean) for the three lots of material by the difference method were 1.03, 0.75, and 0.66. For the polariscopic method the coefficients were 1.48, 0.87, and 0.46.

2. *On Entire Alcohol-Preserved Sample:*—Dry weight is determined as for fresh samples. For solubles and non-starch residues, 5 grams of finely rasped sample is washed into 2-ounce screw-capped wide-mouth bottles with approximately 25 cubic centimeters of 95 per cent ethyl alcohol and the caps screwed down tightly.[4] When the sam-

[3]Malt diastase solution was made by extracting 20 grams of malt diastase with 400 cubic centimeters distilled water for 2 hours and then filtering.

[4]When alcohol preserved samples are to be anaylzed by the sodium hypochlorite polariscopic method, they should be preserved in cold alcohol since heating may result in a low or inaccurate reading. The difference method can be used either on samples preserved in cold or hot alcohol.

ple is to be run, it is washed on hardened filter paper with alcohol as described above for fresh samples. From here on the procedure and calculation are the same as described for fresh samples except that 1.0 should be subtracted from the resulting starch figure (on a fresh weight basis) to obtain values comparable to those obtained by the polariscopic method.

3. *On Alcohol-Insoluble Residue of Alcohol-Preserved Sample:*—In work in which sugar analyses were made, 200 cubic centimeters hot alcohol was added to 50 grams of finely sliced samples in pint fruit jars and boiled 5 minutes in a water bath before sealing. The samples were extracted with a Soxhlet extraction apparatus, and the residue dried and weighed. Starch in the alcohol-insoluble residue was determined after grinding in a ball mill. For the difference method, 125 cubic centimeters of water was added to 1 gram of the ground, oven-dry alcohol-insoluble residue in a 250 cubic centimeter beaker. It was found desirable to wet the material with a small amount of water before adding all the water. After boiling to gelatinize the starch, the procedure was the same as for the fresh samples. The loss in weight of the extracted residue, divided by weight of residue used, multiplied by the weight of the residue, and divided by the weight of the original sample gives per cent of starch on fresh weight basis.

Analyses of several duplicate samples by Dr. Thurber using the amylase polariscopic method showed that it was necessary to subtract 2.0 per cent from the per cent starch (on a fresh weight basis) obtained by the difference method on alcohol insoluble material to obtain values comparable to those obtained by the amylase polariscopic method on this material.

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Hybrid Vigor in Some Tomato Crosses

By Iva M. Burgess, *Maine Agricultural Experiment Station, Orono, Me.*

Hybrid vigor in plant life is a well known phenomenon and its occurrence in tomatoes has been reported by previous investigators. Also the possibility of the commercial use of first generation hybrids has been suggested (1, 4). This report gives the results of comparing certain crosses with existing varieties.

As has been reported by Driver (2) and Hadfield and Calder (3), it was found that there was much variation in the possible worth of different varietal combinations. The material from which this study was made was produced for a breeding project to develop an early tomato resistant to cracking. As a consequence, all crosses have as a parent some progeny from a selection of Red River which was early and quite free from cracking. Other parents were Shirley Bonny Best, Pritchard, Lincoln, Marglobe, Delicious, Cortland, Canadian or selections from one of them. Yield records have been taken from a total of 26 crosses. In addition to the above crosses, numerous crosses of different parentages have been under observation. None of them, however, were sufficiently desirable to warrant continued trial.

Table I summarizes the yield data obtained from the hybrids and their parents. Since interest was primarily in the early crop, data are given only on that harvested up to the last of August or early September. The F_1 material was earlier, as expressed in the amount of early yield, than one and usually both parents. Marglobe hybrids were in this respect somewhat intermediate between the parents. Delicious, a variety of approximately the same season as Marglobe, produced hybrids considerably earlier than the Marglobe hybrids. Cortland and Canadian, varieties similar in bearing habit to Red River did not express hybrid vigor in the earlier yields but did so later. With the exception of the Cortland and Canadian crosses, there was frequently a definite decrease in fruit size of the hybrids as compared with their parents.

The Pritchard crosses were superior to all others in general desirability. The best one was continued in the variety trial plots to learn its possible value as compared with commercial varieties. This particular cross was with Red River selection 44–9, a line which also combined favorably with Shirley Bonny Best. The Bonny Best cross was observed in the trial plots for a few seasons but was discontinued because of the small size of the fruit and the susceptibility to blight infection on the fruit.

Pritchard x Red River 44–9 has now been compared with commercial varieties for seven seasons; in three of which, plots were located in two counties making a total of 10 plots. Table II summarizes the yield data in comparison with that of three of the varieties grown. Speed has been found to be the most dependably early variety of those grown but is not recommended for market use because of the small fruit size. Shirley Bonny Best represents the earliest commercially

TABLE I—COMPARISON OF HYBRIDS AND PARENTS

Variety	Total Yield per Plant and Per Cent Increase (or Decrease) of Hybrid as Compared with Parents				Average Pound per Marketable Fruit	Per Cent Marketable	Distribution of Some Culls† in Per Cent by Count			
	Mid August		First September							
	(Pounds)	(Per Cent)	(Pounds)	(Per Cent)			Cracked	Rough	Small	Blight
Summary of 1934 and 1936 Records										
Shirley	.44	84	3.0	27	.30	68	5	2	2	21
Red River sel.*	.68	21	3.3	12	.31	72	3	9	5	10
5 crosses	.81	—	3.8	—	.26	70	5	3	4	18
Summary of 1934, 1935, and 1936 Records										
Pritchard	.10	470	2.0	59	.38	81	8	4	3	1
Red River sel.	.46	24	2.0	54	.30	65	5	12	11	5
6 crosses	.57	—	3.2	—	.32	77	5	6	3	7
1936 Records										
Lincoln	.31	158	2.3	82	.24	67	3	3	13	12
Red River sel.	.48	67	2.8	52	.27	73	4	11	8	3
1 cross	.80	—	4.2	—	.23	79	2	3	5	12
1935 Records										
Canadian sel.	.12	0	.9	100	.34	70	0	19	9	0
Red River sel.	.12	0	.6	177	.31	70	2	16	10	0
4 crosses	.12	—	1.8	—	.35	73	0	20	0	0
Cortland	Not Grown			—	—	—	—	—	—	—
Red River sel.	.12	33	.6	89	.31	70	2	16	10	0
3 crosses	.16	—	1.2	—	.35	76	3	14	7	0
1934 Records										
Marglobe	.15	147	1.6	9	.39	48	50	2	0	0
Red River sel.	.87	−58	3.9	−56	.35	70	3	7	2	17
2 crosses	.37	—	1.7	—	.36	67	6	1	0	22
Delicious	Not Grown			—	—	—	—	—	—	—
Red River sel.	.87	−14	3.9	2	.35	70	3	7	2	17
6 crosses	.75	—	4.0	—	.30	61	10	2	0	26

*Red River Sel.—Indicates whatever group of the selections was being grown in the seasons for which records are given.

†Other culls included sunscald, rot, and blossom end rot of which there were such small or uniform amounts that their tabulation was not considered of interest for this report. Cracked—marketable shape and size but badly cracked. Rough—catfaces and other misshapen fruit. Small—roughly less than .2 pound. Blight—probably mostly early blight.

desirable variety, while the performance records of Pritchard are given because it is one of the parents of the cross. In this table data on only the marketable yields are given as they are of primary interest in this comparison. Statistical analysis was not considered necessary since, with one exception, the relative positions of the varieties and the cross have been consistent. The exception was in a plot with growing conditions to which Speed responded particularly well, thus producing a greater yield than the Pritchard cross.

In 1936 hybridized seed of Red River 44–9 with Pritchard, Shirley Bonny Best, and Lincoln were sent to a few growers for trial purposes to be compared with other varieties which they might be growing. The final total who returned reports of having grown the material was 13. Of these, nine obtained equal or better yields from the Pritchard cross than from any other variety, three had something earlier. The Shirley Bonny Best cross was preferred by two growers because it was some-

TABLE II—Comparison of Pritchard x Red River 44-9 with Some Important Varieties (Computations Based on 7 Years Data Totaling 10 Plots)

Variety	Marketable Yields (Pounds per Plant)			Average Per Cent Salable	Average Weight per Marketable Fruit (Pound)
	First August	Mid August	First September		
Pritchard ×Red River 44-9...	.21	1.37	3.97	76.3	.33
Speed....................	.18	1.13	3.01	57.5	.26
Shirley Bonny Best..........	.07	.76	2.97	71.5	.30
Pritchard..................	.03	.59	2.18	78.7	.38

what earlier but in general the fruit was considered too small. Trials in northern Maine indicate that this cross may be superior to the Pritchard cross in that locality.

Attempts to make some estimate of the cost involved in producing hybridized seed, for one reason or another, have been abortive. That the use of hybridized tomato seed is feasible has been demonstrated by a Maine grower who produces his own seed for both greenhouse and field crops.

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The Seedling Test Method for Root-Knot-Nematode Resistance

By D. M. Bailey, *Tennessee Agricultural Experiment Station, Knoxville, Tenn.*

THE severity of root-knot nematode in certain areas of Tennessee (3) led to the initiation, in 1939, of a project for the breeding of tomato varieties tolerant to *Heterodera marioni* (Cornu) Goodey. An economical method of testing the materials available was desired, for field tests are expensive and sometimes unsatisfactory because of the inactivity of nematode during the early, cool part of the season.

The literature revealed that Barrons (1) obtained uniform infestations with seedling inoculation of beans. This method was chosen for the testing of tomato varieties and species. It was necessary to use copper oxide for control of the damping-off diseases usually present in greenhouse soils, which harbor severe nematode infestations. Large amounts of this spray material failed to discourage nema attacks upon the young seedlings.

A study was made of the number of seedlings that should be grown in each pot for ease and accuracy of classification. Forty-two pots were planted for these observations. The number of seeds placed in the containers varied from 15 to 75. The final stand of seedlings totaled 1,026, the number in the different pots ranging from 7 to 60. Plants were classified for root injury 21 days after seeding and inoculation. It was found that the number of seedlings growing in each pot affected the classification. The correlation coefficient of –.3524, although not highly significant, indicates the advisability of growing as nearly fixed a number of seedlings in each pot as possible.

During the course of the studies it was found that some of the cultures contained plants escaping infestation. These plants developed galls upon reinoculation. Sixty-nine pots from the preliminary trials and the tests of the commercial varieties were observed for distribution of plants failing to show root knot at time of classification. The number of plants in the different cultures ranged from 1 to 57. The 69 totals— the number of seedlings in each pot contributing one total — were arranged in sequence. These were then separated into six groups to fit the binomial distribution as nearly as possible. The chi-square values for escape plants occurring in the six groups are shown in Table I. The largest single contribution to the highly significant total chi-square value is made by the group containing only a few seedlings in each pot. To be sure, the distribution values shown in this table do not take into account the large number of pots without escape plants, but they do help to elucidate two important questions considered in the studies. First, the amount of inoculum applied to each pot apparently is not a limiting factor in producing infestations when the quantity of seedlings per pot is kept below the upper limits given in Table I. Second, since from 25 to 30 seedlings are desirable for ease and accuracy of classification, the planting of groups of that size is advisable. This would prevent the occurrence of some of the escapes.

TABLE I—DISTRIBUTION OF ESCAPE PLANTS IN SIX GROUPS OF TOMATO SEEDLINGS INOCULATED AT TIME OF PLANTING

Group	Range of Plants Per Pot (Number)	Total Seedlings		Escape Seedlings			
		Theoretical Binomial Distribution of Plants in Each Group (Number)	Deficit or Surplus Plants in Group† (Number)	Observed Escapes in Group (Number)	Calculated Escapes in Group (Number)	O—C (Number)	$\frac{(O-C)^2}{C}$
1........	1–10	54	1	14	5.8	8.2	11.59**
2........	11–21	270	–4	37	28.9	8.1	2.27
3........	22–28	540	4	64	57.8	6.2	0.66
4........	29–41	540	–12	49	57.8	–8.8	1.34
5........	41–51	270	6	16	28.9	–12.9	5.76*
6........	57	54	3	5	5.8	–0.8	0.11
	Totals	1728	–2	185	185.0	——	21.73**

†Calculations made without allowance for deficit or surplus plants in each group.
**Highly significant value.
*Significant value.

From the preliminary findings, the following method was found satisfactory in testing an estimated 36,000 *Lycopersicon* seedlings: Two-inch pots were filled with the nematode-infested sandy loam soil to within ¾ inch of the top of the container. Approximately 3 grams of chopped root knots from infested tomato plants were then pressed into the soil of each pot. Seventeen cubic centimeters of red copper oxide—1 part Cu_2O to 57–63 parts water—was poured over the surface of the soil and the inoculum. To permit movement of the larvae from the chopped root knots into the soil, the pots were allowed to stand for 2 days before the seeds were planted. During this time the pots were covered to prevent desiccation of the soil and the inoculum. From 30 to 40 seeds were placed in each pot and sprayed with the copper oxide solution before covering with fine sand. All pots were again covered with paper until the seedlings emerged. Water was supplied in sufficient quantity to maintain optimum growing conditions by alternating between tap water and a solution containing 1 part Cu_2O to 475 parts water, until three applications of this solution had been made. The plants were classified into six groups according to the amount of injury to root and hypocotyl. These observations were made from 19 to 21 days after seeding.

Five species of *Lycopersicon* have been tested by this method. Ninety-five commercial varieties and several selections of *L. esculentum* from experimental laboratories failed to show tolerance. With three possible exceptions, no tolerance was found in 420 seed lots of *L. esculentum* from the United States Bureau of Plant Industry, Division of Plant Exploration and Introduction. Three other species, *L. glandulosum, L. hirsutum,* and *L. pimpinellifolium,* also were found susceptible. *L. peruvianum* appears to be more tolerant to root knot than the other species tested. Selections have been made from 11 of the 25 introduced seed lots of this species. Twenty of the original 299 selections are still free of galls after growing in nematode-infested soil for a period of 6 months.

The ability of nematode to become adapted to a new host species

(2) justifies a conservative attitude toward the ultimate selection of highly root-knot-tolerant plants, but the recently conducted tests indicate that there are possibilities for the breeding of tolerant varieties.

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Heterosis in the Tomato as Determined by Yield

By ARTHUR MEYER and N. D. PEACOCK, *University of Tennessee, Knoxville, Tenn.*

THE yield per acre of tomatoes in Tennessee is low, being roughly one-half the average of the United States, and one-third of the highest-producing states (7). The low yield is attributed usually to pathological causes, especially foliar diseases. Breeding of tomatoes to meet this condition has been in progress for years, but little or no use has been made of the increased vigor obtained in certain F_1 crosses.

Wellington (8, 9), Stuckey (6), and Hayes and Jones (3) all reported increased yields from F_1 hybrids. But interest in the subject apparently waned after 1922, in spite of the fact that F_1 hybrids were reported to be practical. Hadfield and Calder (2), in New Zealand, revived the subject in 1936, and reached the same conclusions as the earlier investigators.

Kakizaki (4), reporting in 1931 on hybrids of eggplant, stated that two crosses had been selected and were being used for commercial purposes in Japan. Curtis (1) has shown that a hybrid of summer squash is entirely practical and highly productive.

The popularity of corn hybrids, and the increased interest in F_1 hybrids of other plants, prompted the writers to investigate further the possibility of utilizing heterosis in the tomato as a means of increasing the yield of this fruit.

PROCEDURE

Twelve reciprocal and three single crosses were made and compared with their five parental varieties. The selection of the parental varieties was based on suggestions found in reports of previous investigations. Wellington (9) advised the use of Earliana. Hadfield and Calder (2) considered that varieties showing marked differences would show greater heterosis when crossed than varieties that are more alike in morphological respects. To maintain desirable fruit size, however, small-fruited varieties would have to be eliminated. A study of varietal relationship (5) and production records in Tennessee led to the conclusion that some of the most promising parental varieties would be Earliana, Marglobe, Indiana Baltimore, and Nystate. Reciprocal crosses of these varieties were made. In addition, Bonny Best was used as the pollen parent in crosses with Earliana, Marglobe, and Indiana Baltimore. Earliana and Nystate were used in an effort to obtain earliness, and Marglobe and Indiana Baltimore were used to secure large yields, since they normally produce more fruit under Tennessee conditions than other varieties. Bonny Best was included because of its former popularity.

Plants of these varieties and hybrids were grown in the usual manner, and fruited in 1939. In all except Earliana ♀ x Bonny Best ♂ the plots consisted of five plants each, with plants spaced 3½ feet each way. The plots were replicated four times and randomized, and the plants were pruned to one trunk and trained to stakes. The fruit was

TABLE I—Calculated Yields per Acre of Parental Varieties and F_1 Hybrids

♀ Parent	♂ Parent	1939 U. S. No. 1 (Tons)	1939 U. S. No. 2 (Tons)	1939 Total (Tons)	1940 U. S. No. 1 (Tons)	1940 U. S. No. 2 (Tons)	1940 Total (Tons)	Two-year Ave (Tons)	Per Cent Increase Over Indiana Baltimore
Indiana Baltimore	Selfed	6.05	5.36	11.41	4.10	2.73	6.83	9.12	—
	Earliana	4.72	7.08	11.80	4.28	3.33	7.61	9.70	6.36
	Marglobe	5.74	7.87	13.61	6.79	3.34	10.13	11.87	30.15
	Nystate	3.50	8.05	11.55	3.02	2.76	5.78	8.66	–5.04
	Bonny Best	2.24	7.33	9.57	—	—	—	—	—
Earliana	Selfed	1.66	8.33	9.99	3.89	2.88	6.77	8.38	–8.11
	Indiana Baltimore	3.31	7.06	10.37	5.40	3.24	8.64	9.50	4.16
	Marglobe	3.65	9.73	13.38	5.70	4.01	9.71	11.54	26.53
	Nystate	1.44	6.98	8.42	—	—	—	—	—
	Bonny Best	1.84	8.70	10.54	—	—	—	—	—
Nystate	Selfed	1.39	8.76	10.15	3.34	3.29	6.63	8.39	–8.00
	Indiana Baltimore	2.45	8.31	10.76	3.52	3.65	7.17	8.96	–1.75
	Marglobe	2.82	10.25	13.07	6.54	4.53	11.07	12.07	32.43
	Earliana	2.10	7.40	9.50	—	—	—	—	—
Marglobe	Selfed	1.55	6.25	7.80	2.89	2.40	5.29	6.54	–28.28
	Bonny Best	1.70	9.59	11.29	3.73	4.27	8.00	9.64	5.70
	Earliana	5.72	7.15	12.87	6.69	3.11	9.80	11.33	24.23
	Nystate	1.87	10.19	12.06	4.72	4.98	9.70	10.88	19.29
	Indiana Baltimore	3.85	7.54	11.39	4.64	4.50	9.15	10.27	12.61
Bonny Best	Selfed	1.51	7.40	8.91	3.66	2.87	6.53	7.72	–15.35

graded according to U. S. Standards for fresh tomatoes, and yields were recorded in pounds.

The supply of seeds of the original stock was ample for a repetition of the plantings in 1940. The three hybrids giving the lowest yields in 1939 were omitted; and another cross was dropped because of low germination and low yield. The remaining varieties and hybrids were planted in triplicate plots of five plants each, spaced 3 feet apart each way.

TABLE II—Average Weight of Fruits from Varieties and Hybrids in 1940, Listed in Descending Order of the Size of U. S. No. 1 Fruits

Variety or Hybrid	Average Weight of Fruits: U. S. No. 1 (Pound)	Average Weight of Fruits: U. S. No. 2 (Pound)
Marglobe♀ ×Bonny Best♂	.399	.466
Nystate ×Indiana Baltimore	.391	.412
Indiana Baltimore ×Marglobe	.370	.352
Marglobe ×Nystate	.353	.364
Marglobe	.345	.339
Earliana ×Marglobe	.344	.383
Marglobe ×Indiana Baltimore	.343	.394
Indiana Baltimore	.335	.354
Bonny Best	.334	.350
Indiana Baltimore ×Earliana	.328	.390
Indiana Baltimore ×Nystate	.324	.351
Earliana ×Indiana Baltimore	.319	.336
Earliana	.310	.338
Nystate	.309	.305
Nystate ×Marglobe	.305	.316
Marglobe ×Earliana	.303	.288

TABLE III—Average Number of Fruits per Plant in 1939–1940, Listed in Descending Order of the Total

Variety or Hybrid	Fruits Per Plant		
	U. S. No. 1 (Number)	U. S. No. 2 (Number)	Total (Number)
Marglobe♀ ×Earliana♂	10.5	9.7	20.2
Nystate ×Marglobe	7.1	10.8	17.9
Indiana Baltimore ×Marglobe	8.7	8.0	16.7
Marglobe ×Nystate	4.9	10.9	15.8
Earliana ×Marglobe	6.1	9.4	15.5
Earliana ×Indiana Baltimore	6.7	8.5	15.2
Nystate	3.7	10.5	14.2
Marglobe ×Indiana Baltimore	6.1	8.0	14.1
Indiana Baltimore ×Earliana	6.3	7.3	13.6
Indiana Baltimore	7.7	5.6	13.3
Earliana	4.2	9.0	13.2
Bonny Best	3.7	8.8	12.5
Indiana Baltimore ×Nystate	4.8	7.5	12.3
Marglobe ×Bonny Best	3.3	8.4	11.7
Nystate ×Indiana Baltimore	3.9	7.6	11.5
Marglobe	3.2	7.0	10.2

Results

Table I shows the calculated yields per acre, and the per cent increase over Indiana Baltimore, the variety which gave the highest yield. It is apparent that the most productive hybrids gave substantial increases over the yields of parental varieties.

Table II gives average weights of No. 1 and No. 2 fruits grown in 1940. It shows that some hybrids produce larger fruits than their parents, some are intermediate between the larger and the smaller parent, and some are smaller than either parent. The two hybrids producing the smallest fruits, however, were among those making the highest yields.

The average number of fruits produced per plant is shown in Table III. Here again it appears that certain hybrids are superior, some intermediate, and others inferior to their parents. The five hybrids making the highest yield per acre also produced the highest number of fruits per plant. Two of these produced the smallest fruits.

TABLE IV—Total Number of Fruits in U. S. Grades Picked from All 20 Plants the First Five Harvest Dates (July 1, 3, 5, 7, and 10, 1939) Listed in Descending Order of Total Number of Fruits

Variety or Hybrid	U. S. No. 1	U. S. No. 2	Total
Marglobe♀ ×Earliana♂	14	37	51
Earliana ×Indiana Baltimore	8	41	49
Earliana ×Marglobe	6	31	37
Indiana Baltimore ×Earliana	9	27	36
Nystate	3	32	35
Nystate ×Marglobe	2	28	30
Indiana Baltimore ×Marglobe	4	24	28
Bonny Best	3	25	28
Marglobe ×Nystate	0	25	25
Nystate ×Indiana Baltimore	2	22	24
Indiana Baltimore	7	14	21
Marglobe ×Indiana Baltimore	3	18	21
Indiana Baltimore ×Nystate	2	19	21
Earliana	3	17	20
Marglobe ×Bonny Best	0	12	12
Marglobe	0	11	11

An important factor in the production of tomatoes for the fresh-fruit market is earliness. The records for 1939 give a satisfactory picture of earliness in the varieties and hybrids studies. A severe infestation of tomato fruit worm in 1940 delayed the first marketing until July 9, as compared with July 1 the previous year. The total number of U. S. No. 1 and U. S. No. 2 fruits harvested from the 20 plants of each variety and hybrid under trial in 1939 is shown in Table IV. The first four hybrids in 1939 were the first four in 1940. The large number of fruits in both grades, especially of U. S. No. 1, produced by four hybrids, and by Indiana Baltimore, should be of great importance to growers interested in early production for market.

An interesting fact is to be observed in the position that Marglobe holds in the various tables. This well-known and popular variety produced the lowest quantity of fruit, the smallest number of fruits early in the season, and the smallest number of fruits per plant throughout the season. The average weight of each Marglobe fruit was greater than that of any of the other parental varieties. The strain of Marglobe used in this work was obtained from one of the largest and most reputable seed companies in the United States and was their best strain. A strain of Marglobe from another source produced only slightly better than the parental strain in 1940. Nevertheless, the Marglobe used in this project proved to be satisfactory as either male or female parent, the former being somewhat superior, as shown in Table I.

The cross of Marglobe ♀ x Earliana ♂ produced an exceptionally smooth fruit with the greatest freedom from cracking. This was very noticeable during the picking season both years.

Conclusions

From the data presented herein the following conclusions are drawn:

1. Certain hybrids of some standard varieties of tomatoes have proved to be superior to their parents by giving higher yields of fruit early in the season and higher total yields.
2. Of the varieties studied, Indiana Baltimore gave the highest yield.
3. Hybrids of Nystate ♀ x Marglobe ♂, and Indiana Baltimore ♀ x Marglobe ♂ were sufficiently superior to the highest-yielding variety to be of value as a canning crop.
4. Marglobe ♀ x Earliana ♂ was sufficiently superior in early yields and total yields to be useful for the fresh-fruit market. The reciprocal cross was almost as good.
5. Nystate ♀ x Marglobe ♂ made almost double the yield of the male parent, which is a standard and commonly grown variety.

It is the opinion of the writers that F_1 hybrids of tomatoes may be of value to growers in general. Certain crosses should be of special value under intensive culture.

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Green Cotyledon, a New Character in the Mature Lima Bean (Phaseolus Lunatus L.)

By Roy Magruder and R. E. Wester, *U. S. Horticultural Station, Beltsville, Md.*

SEEDSMEN have selected toward green seeded limas for a long time and have achieved varying shades of green in the seed coat. As far as the writers know, green cotyledons in the dry or mature lima bean were first recognized and saved for breeding purposes in 1936 and 1937 by representatives of seed companies in Colorado and California. This new type was first publicly offered for sale as Green Seeded Henderson in the January 1, 1940 catalog of the Associated Seed Growers, Inc., although it was sampled out to a few canners in 1939. The same type was entered in the 1940 All America vegetable trials by Ben Fish and Son. It is reported that F. H. Woodruff and Son plan to accept contracts for the 1941 crop of their strain.

A few seeds were discovered during the hand picking of commercial seed crops of the Henderson Bush variety. The next generation plants and pods were almost identical with the Henderson Bush variety but practically all seeds were of the green cotyledon type, indicating that the new type probably arose as a mutation.

Following receipt of this type in the early spring of 1940, the writers made a search in remnants of green seeded selections from hybrids between Henderson and Fordhook and found two seeds in the 1939 progeny of one plant and six from that of another. The plants from these eight seeds are not yet mature.

Description

In season of maturity and in productiveness, the Henderson green cotyledon type seems to be the same as Henderson Bush judged on the basis of several trials during 1940 in the eastern states.

Plant size and habit of growth are identical with Henderson Bush, but under certain conditions the leaves are reported to be slightly darker green. At Beltsville, Maryland, and in New York State there was no discernible difference.

Pod size and shape are likewise identical with Henderson Bush except that the pods do not turn yellow as they mature but dry green and then later bleach out to a straw yellow when exposed to the sun and weathering influences. Pods that mature under the leaves are green in color, whereas those above the foliage usually fade to straw yellow in color. As the plant loses its leaves the lower pods also become bleached to straw yellow color.

The immature beans are indistinguishable from Henderson Bush in size, shape and color, and it is not until the mature beans of Henderson Bush lose the green color and turn white or light cream that the green cotyledon type can be identified. The fresh dry beans of the green cotyledon type are silvery blue green (11 B1 Maerz and Paul (1)) in color with the thin colorless testae, or seed coats, in place. With the seed coats removed the color varies around 20 G 2.

Continued exposure to sunlight and weathering out of doors has resulted in fading of the green color from the cotyledons of seeds of plants which produced only green cotyledon seeds when grown in the greenhouse and harvested before the pod sutures opened. In several cases in the greenhouse when the pods on the terminal cluster were allowed to remain for several weeks after they were dry enough to harvest, the beans in them had faded to almost white in color. The dry, green-cotyledon seeds gradually fade after harvest if exposed to light. It is not known at this time how long the green color will be retained in dark storage. Small lots stored in kraft paper envelopes in seed cabinet drawers have shown no noticeable diminution of color in 6 months.

Preliminary Genetic Data

The parent plants of the crosses reported herein and succeeding generations were grown in a greenhouse with screened ventilators and doors to prevent entrance of flies, bees, or other large insects, and were fumigated and sprayed at frequent intervals to control thrips and other insects.

As shown in Table I, eight green-cotyledon plants (G parents) were used in the crosses with seven plants having white or light cream-colored cotyledons (P parents). All the F_1 seed had white cotyledons regardless of whether the green or white type was the female parent, indicating that white was dominant to green. Due to the difficulty of hybridizing lima beans, no back-crosses were made.

The F_2 results in Table I indicate rather clearly that the green-cotyledon character is a monogenic recessive to white or light cream colored cotyledon. Although no reciprocal crosses involving the same parent plants were successful, crosses 429, 431, and 432 indicate no maternal inheritance in this material. It should be noted that the four progenies (403b, 413a, 415a, and 423b) show deviations great enough to be due to causes other than chance, but other progenies from the same parents approach rather closely the expected 3:1 segregation.

Commercial Possibilities

Canners, and especially freezers, have long sought for a lima bean that would retain its green color until mature, hoping thereby to avoid the costly hand separation of white from green beans following the blanching process. This separation serves a double purpose in that it removes the hard, mature beans as well as the white, immature ones and results in a product of uniform quality. Since the hard, mature beans of the green-cotyledon type cannot be separated on a color basis from the immature beans it will be necessary to provide some other method such as brine or specific gravity separation. The new method will need to be very efficient, for the inclusion of mature and immature beans in the same package will adversely affect the eating quality. The introduction of this new color type may, therefore, require expensive machinery and an additional costly operation, which if not thoroughly done, may result in a poor quality pack.

Analyses made by A. Kramer in the Horticulture Laboratory of the

TABLE I—F_2 SEGREGATION IN CROSSES BETWEEN GREEN- AND WHITE-COTYLEDON PARENTS (BELTSVILLE, MARYLAND, 1940)

Pedigree Number	Parents		Number Seed With Cotyledons—		Chi† Square
	Female	Male	White	Green	
403a	G1*	P2*	167	70	2.60
403b	G1	P2	127	65	8.09
403c	G1	P2	211	77	.47
404a	G1	P3	253	89	.19
404b	G1	P3	192	78	2.17
405a	G2	P6	154	42	1.33
405b	G2	P6	72	19	.83
405c	G2	P6	181	64	.16
406a	G2	P6	181	62	.03
406b	G2	P6	87	33	.40
406c	G2	P6	188	75	1.73
407a	G3	P2	205	87	3.58
409a	G4	P1	204	84	2.67
409b	G4	P1	172	67	1.17
409c	G4	P1	48	20	.71
412a	G4	P4	142	40	.88
412b	G4	P4	101	45	2.64
412c	G4	P4	215	69	.08
413a	G4	P4	146	28	7.36
413b	G4	P4	43	22	2.71
414a	G6	P6	165	58	.12
414b	G6	P6	46	15	.01
415a	G6	P6	170	39	4.48
415b	G6	P6	107	36	.002
415c	G6	P6	184	46	3.07
419a	G7	P1	195	66	.01
419b	G7	P1	121	45	.39
419c	G7	P1	185	49	2.05
423a	G9	P9	205	71	.08
423b	G9	P9	146	71	6.89
425a	G9	P1	212	68	.08
425b	G9	P1	53	14	.60
426a	G9	P1	222	65	.84
426b	G9	P1	141	43	.26
426c	G9	P1	254	74	1.04
427a	G11	P2	142	56	1.13
427b	G11	P2	130	42	.03
427c	G11	P2	176	59	.002
428a	G11	P4	205	83	2.24
428b	G11	P4	136	44	.03
429a	P1	G6	156	44	.96
429b	P1	G6	252	70	2.83
431a	P11	G2	172	74	.14
431b	P11	G2	3	0	1.00
432a	P11	G2	179	53	.77

*G = green-cotyledon parent.
P = white-cotyledon parent.
†For 3:1 ratio; 5 per cent point equals 3.841.

University of Maryland indicate that there is no significant difference in ascorbic acid content between white- and green-cotyledon beans of the same stage of maturity (from the same pod).

To prevent the appearance of white seeds in the harvested crop due to field hybridization by insects (2), it will be necessary to isolate fields of the green-cotyledon type far enough from fields of white-cotyledon limas so that bees and other insects will not fly from one to the other. This may not be practicable in regions where large acreages are grown. The other alternative would be to use only the green-cotyledon type in certain large sections.

Unless a strain can be developed that will not fade in the field, much of the anticipated benefit of this new type will not materialize. The white or faded beans will need to be removed by hand unless a satis-

factory specific gravity method can be developed that will remove them along with the hard seed of the green-cotyledon type.

A sample of new-crop, dry, green-cotyledon seed, when soaked overnight and cooked until tender, lost enough green color in the cooking process to make the sample unattractive. The cooked material was variable in the amount or shade of green in different regions of the same bean. The flavor or texture was not superior to that of Henderson Bush cooked in the same manner.

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A Study of Natural Crossing in Peppers (Capsicum Frutescens)

By M. L. Odland and A. M. Porter, *University of Connecticut, Storrs, Conn.*

PLANT breeders and seedsmen disagree considerably in their opinions relative to the amount of natural cross-pollination that occurs in the cultivated pepper. Even a very small per cent of natural crossing between plants in adjacent rows is upsetting in a breeding program where pure lines are desired. In seed production knowledge relative to natural crossing is a great aid in determining the isolation necessary in the seed plots. No work, to the writers' knowledge, has been done which indicates the actual amount of cross-pollination that takes place in this crop.

Observations Relative to the Occurrence of Cross-Pollination

A study of the pepper and tomato seed sold on the open market in Connecticut has been made (1). This study indicates that, in general, there is a greater degree of variability in both fruit and plant type in peppers than in tomatoes. This would suggest a higher degree of cross-pollination in the former. As to the nature of the variability in the peppers, it was found that, as a rule, the samples were fairly true to name, or at least approached the type as indicated by the label on the packet. However, there were in many cases a high per cent of off-type plants, some of which were distinctly off-type while others were off-type to a lesser degree. This situation would suggest that a considerable amount of cross-pollination between varieties had probably occurred at some time in the seed plots.

Further observations of strain and variety trials in Connecticut, Minnesota, and other states have indicated the probability of considerable cross-pollination. In certain cases, a small per cent of vigorous, distinctly off-type plants are found in a strain. Often the progeny of such plants segregate for distinct types suggesting that they were the F_1 generation (or later generations) of crosses between varieties.

Materials and Methods

Vegetable crop rotation study plots planted to peppers in 1938 were utilized in this cross-pollination study. These plots were 20 by 36 feet and were isolated one from another, although in the same general field; thus, they were subjected to similar environmental conditions. The planting distance was 3 feet by 1.5 feet. The variety used in the vegetable crop rotation study was a true breeding strain of Harris Early Giant. This variety carries dominant genes for immature fruit color, mature fruit color, fruiting habit, and position of the fruit. These factors, together with fruit shape, fruit size, and certain plant characteristics, made it possible to differentiate the F_1 plants resulting from cross-pollination between this variety and the other varieties used in the study. Table I lists the varieties and indicates the differentiating characters used to identify plants resulting from cross-pollination.

TABLE I—DESCRIPTION OF HARRIS EARLY GIANT, THE "DOMINANT TESTER" VARIETY AND THE OTHER VARIETIES CONSIDERED IN THE STUDY

Variety	Immature Fruit Color	Mature Fruit Color	Fruiting Habit	Fruit Position	Fruit Shape
Harris Early Giant	Dark green	Red	Normal	Pendant	Blocky
Oshkosh	Dark green	Yellow	Normal	Upright	Blocky
Golden Dawn	Dark green	Yellow	Normal	Pendant	Blocky
Cayenne	Dark green	Red	Normal	Pendant	Long
White Sweet	Sulphury white	Red	Normal	Pendant	Tomato
Red Cluster	Dark green	Red	Cluster	Upright	Long
Ornamental	Sulphury white	Red	Normal	Upright	Blocky

The plan of study was as follows: Immediately after transplanting time a single plant of Harris Early Giant was removed from the center of a plot and replaced with a recessive plant. Six recessive varieties were studied. Two plants of each variety were used, *i.e.*, there were two replications differentiated by location in the field. Plants in the first replication are referred to as Number 1 plants, and those in the second replication are referred to as Number 2 plants. Seed was saved from these recessive plants and was grown the following year. From observation, the per cent of cross-pollinated plants could be determined. For example, in the two cultures of Oshkosh, any plant that bore red fruit or fruit in a pendant position were known to be crosses.

EXPERIMENTAL RESULTS

The results of the experiments are given in Table II. The number of plants grown, the number of crosses (plants showing characters of the "dominant tester" Harris Early Giant), and the per cent cross-pollination is given. In all cases, seeds from two plants were tested. No difficulty was experienced in determining which plants were a result of cross-pollination.

The variety Oshkosh, which is a good representative of the commercially important varieties, exhibited 8.2 per cent cross-pollination

TABLE II—AMOUNT OF NATURAL CROSS-POLLINATION THAT OCCURS WHEN CERTAIN RECESSIVE VARIETIES ARE SURROUNDED BY HARRIS EARLY GIANT AS A "DOMINANT TESTER" VARIETY

Recessive Variety	Plant No.	No. of Plants	No. of Crosses	Cross-Pollination (Per Cent)
Oshkosh	1	98	8	8.2
	2	100	10	10.0
	Average	—	—	9.1
Golden Dawn	1	50	10	20.0
	2	50	13	26.0
	Average	—	—	23.0
Cayenne	1	69	7	10.1
	2	67	8	11.9
	Average	—	—	11.0
White Sweet	1	144	11	7.6
	2	87	11	12.6
	Average	—	—	10.1
Red Cluster	1	33	6	18.2
	2	79	8	10.1
	Average	—	—	14.1
Ornamental	1	41	15	36.8
	2	41	11	26.8
	Average	—	—	31.8

TABLE III—Analysis of Variance of the Amount of Cross-Pollination in Peppers

Variation Due To	Degree of Freedom	Mean Square	F
Between varieties	5	163.13	5.64*
Within varieties	1	1.02	—
Error	5	23.10	—
Total	11	84.74	—

*F value significant.

in plant No. 1 and 10 per cent in plant No. 2. The average per cent cross-pollination is 9.1. Golden Dawn, a somewhat similar variety, exhibited 20 per cent cross-pollination in plant No. 1 and 26 per cent in plant No. 2 with an average of 23 per cent. Golden Dawn frequently appears to produce an insufficient amount of viable pollen. This may partially explain the greater amount of natural cross-pollination for this variety. If the data from these two varieties are taken as an indication of the amount of natural cross-pollination in the commercial bell peppers, we must conclude that approximately 16 per cent cross-pollination occurs in the group when the plants are grown in close proximity.

In the variety Cayenne, the progeny of plant No. 1 showed 10.1 per cent cross-pollination, and the progeny of plant No. 2 showed 11.9 per cent cross-pollination. The average is 11 per cent. In White Sweet plant No. 1, 7.6 per cent of the progeny were cross-pollinated, while 12.6 per cent of the progeny of plant No. 2 were cross-pollinated. The average is 10.1 per cent. In Red Cluster plant No. 1 showed 18.2 per cent cross-pollination, while plant No. 2 showed 10.1 per cent, with an average of 14.1 per cent. One progeny of Ornamental showed 36.8 per cent cross-pollination; the other showed 26.8 per cent. The average is 31.8 per cent.

The average per cent cross-pollination for the six varieties is 16.5. The range is from 7.6 per cent cross-pollination in White Sweet, plant No. 1, to 36.8 per cent in Ornamental, plant No. 1. The lowest average per cent cross-pollination is found in Oshkosh, while the highest is found in Ornamental. When the analysis of variance is calculated for the data presented in Table II it is found that the several varieties differ significantly in regard to amount of cross-pollination exhibited. The analysis also indicates that plants within a variety are similar relative to cross-pollination.

Five groups of peppers are represented in the study, as follows: Oshkosh and Golden Dawn in the Bell group, Cayenne in the Cayenne group, White Sweet in the Tomato group, Red Cluster in the Tobasco group, and Ornamental in the Celestial group. The results of the study would appear to indicate that natural crossing takes place between all types of peppers.

Discussion and Conclusions

The results of this experiment indicate that, in general, there is enough natural crossing in the cultivated pepper to necessitate a certain amount of isolation of seed plots and isolation or protection in breed-

ing work. The distance of isolation or the amount of protection required was not determined.

The data appears to indicate that there is some difference in the amount of natural crossing that occurs between the various varieties. The data also indicates that natural crossing occurs equally or as readily between varieties belonging to different groups as between varieties in the same group. In the study, no data was obtained that indicated that any particular group or variety was entirely self-fertilized.

The pepper flower is rather inconspicuous and non-fragrant, a fact that would suggest insect pollination not very likely. Erwin (2) found that the flowers produced nectar and that insects did at times visit them. The writers are of the opinion that honey bees are largely responsible for the cross-pollination that takes place. This insect has been found working on the pepper plant rather often. The presence of the bees is rather spasmodic, however, as they are found only on certain warm, bright days. The presence of bees in the vicinity may have a bearing on the amount of cross-pollination. Thrips are usually present in the blossoms and, no doubt, transfer pollen from blossom to blossom on the same plant, and also from plant to plant when the planting in the row is so close that the foliage touches. The amount of cross-pollination that can be attributed to insects will, no doubt, vary from season to season and from place to place, depending upon the numbers and kinds of insects present, as determined by the climate and other factors. No mention of the wind as an agent in the dissemination of pollen has been made. However, if, on a warm, clear day, a blossom is tapped with a pencil, a small "cloud" of pollen is clearly visible. It is conceivable to see how the wind might whip a plant slightly, causing the pollen to be dislodged and carried to flowers on nearby plants. In all probability, the wind accounts for only a very small per cent, if any, of the cross-pollination that takes place in this crop.

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Nomographic Charts for the Rapid Computation of Measurement Ratios of Horticultural Products[1]

By KEITH C. BARRONS, *Michigan Agricultural Experiment Station, East Lansing, Mich.*

A NUMBER of workers have used measurement ratios in describing various vegetables. With tomatoes, for example, the ratio of the depth of fruit to the greatest diameter expressed as a percentage has been employed as a measurement of fruit shape. Boswell, *et al.* (2) used this "shape index", as it may be called, in describing the characteristic fruit shape of tomato varieties. At least one seedsman has found it advantageous to use average depth/width ratios in catalog descriptions of this vegetable.

In a study of the effect of environment on shape in cabbage, Flory and Walker (3), calculated the ratio of the length of heads to their greatest width. In connection with an investigation of the heart development of celery stored under various conditions, the writer has found it convenient to express as a percentage the ratio of the length of petiole to the entire length of leaf.

It is conceivable that such measurement ratios might be used more widely with a number of horticultural crops, not only in varietal descriptions and breeding work, but also in studies where shape may be influenced by environment or cultural practices. Apparently most, if not all, workers who have used such measurement ratios have made and recorded individual measurements and calculated the ratios later. The writer has found it advantageous to prepare nomographic charts which may be used in conjunction with calipers for obtaining such ratios directly. Thus considerable time may be saved by eliminating the necessity of recording separate readings and making calculations.

The theory and construction of nomographs of various types has been discussed by Allcock and Jones (1) and Mavis (4). In brief, the nomograph devised for the rapid computation of measurement ratios of horticultural products consists of ordinate and abscissa axes of equal length, each graduated with the scale found on the calipers to be used, and as long as the measurements likely to be encountered with the material under investigation. A third line of equal length parallel to the ordinate axis and intersecting the origin of the abscissa axis is graduated in the form of a ratio scale on the basis of 0–100. The chart is completed by connecting with diagonal lines the intersection of the ordinate and abscissa axes with a number of points on the ratio scale. If percentage ratios greater than 100 are likely to be encountered, the scale may be extended to any desirable degree, and if only a narrow range of ratios or measurements are found with the material on hand only the essential portion of the nomograph need be constructed.

A nomograph prepared by the writer for determining the shape index of tomatoes and the method in which it is used is shown in Fig. 1, a, b, and c. The vernier calipers are calibrated both in inches

[1]Journal Article No. 498 (n.s.) from the Michigan Agricultural Experiment Station.

FIG. 1. (a)

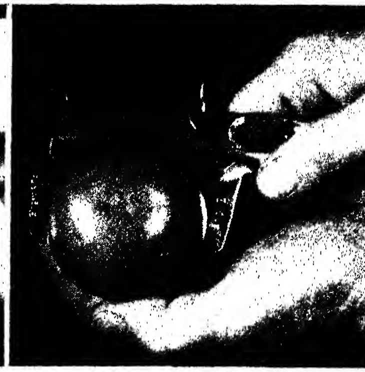

FIG. 1. (b)

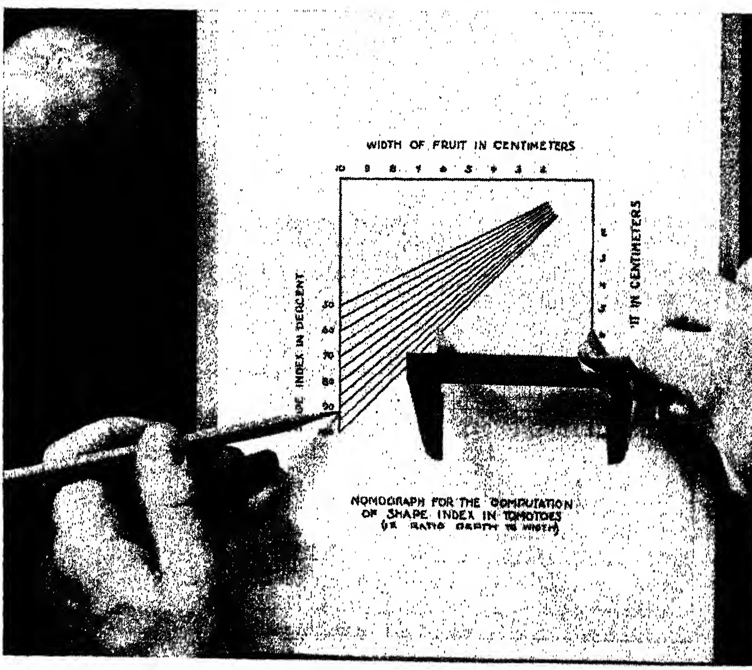

FIG. 1. (c)

FIG. 1. Steps in the use of a nomographic chart for the determination of shape index in tomatoes. (a) Obtain the depth measurement (polar diameter) and make a mental note of the reading. (b) Fit the calipers to the greatest width (equatorial diameter). (c) Place one point of the calipers on the "depth" scale corresponding to the reading obtained, allow the other point to fall on the chart parallel to the first, and using the necessary interpolation, follow out the diagonal line to the ratio scale where a direct reading in per cent may be obtained.

and centimeters; however, the metric scale is used in making these measurements. The chart is constructed on metric graph paper fastened to a piece of cardboard. First, the depth measurement is taken and a mental note made of the reading. The calipers are then fitted to the greatest width, and without reading this measurement, they are inverted with one arm placed on the ordinate axis at the point corresponding to the depth measurement and the other arm perpendicular to it. By following out the closest diagonal line on which the caliper point falls and using the necessary interpolation, a fairly accurate depth/width ratio may be obtained on the ratio scale. In this case, no measurements greater than 10 centimeters were encountered so each axis was made 10 centimeters in length. When 10 measurement units may be used the calibration of the ratio scale is greatly facilitated as the graduation coincides with that on the ordinate axis.

A very similar nomograph as shown in Fig. 2 may be employed in obtaining length/width ratios of cabbage heads. In this case, calipers and graph paper graduated in inches are used. The same calipers with a chart constructed to fit the material on hand were employed with celery to obtain the ratio of the length of the petiole to the entire leaf (Fig. 3). The calipers available for this work had no pointed arms, usually employed for inside measurements, such as were present on

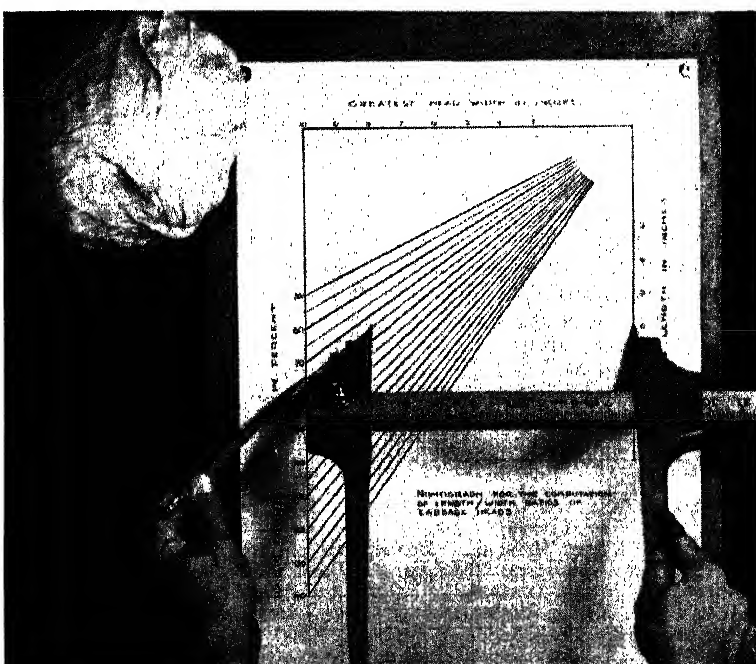

Fig. 2. A similar nomograph used in determining the depth/width ratios of cabbage heads

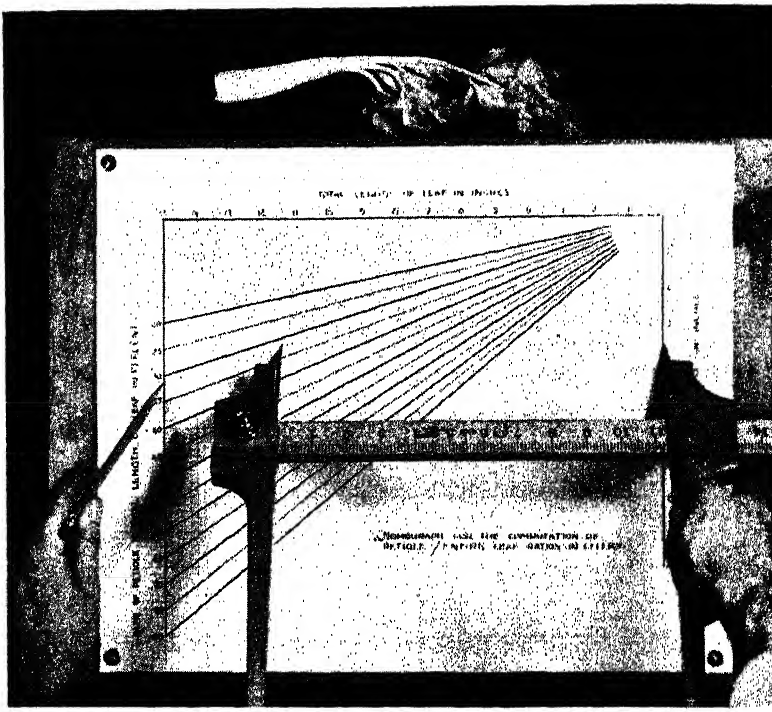

FIG. 3. Nomograph employed for the determination of petiole/entire leaf ratios in celery.

those used for tomatoes. The necessary arms were therefore made of metal and attached with small screws.

Although nomographs such as described above may have their most useful application as a short-cut in computing ratios where linear measurements are made and where calipers may be used, they might also be of value in work with weights and other measurements. One need only locate the point of intersection of lines extending perpendicularly from the two measurements on the ordinate and abscissa axes and then, using the necessary interpolation, follow out the nearest diagonal line to the ratio scale.

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Correlation from Ranks, for Horticultural Research

By JOHN W. CRIST, *Michigan State College, East Lansing, Mich.*

AT the two previous meetings of the society I offered two procedures in correlation for your consideration. I would now affect the presentation of a third one. It is known as the method of Correlation from Ranks.

This method is not new in the realm of mathematics. It's use in certain fields of research is not unknown. In horticulture, however, it has not as yet been appreciated and adopted.

Essentially, the coefficient of correlation from ranks (ρ) is a modified form of the ordinary coefficient of linear correlation. In it's determination, the ranks of the two variates, instead of their actual values, are formed and utilized. The process itself is simpler and more readily accomplished than that of the Pearsonian linear procedure, and, at the same time, may yield as much information as is required.

Some data from a laboratory experiment on the rate of dehydration (under uniformly controlled conditions) of made-up biocolloidal cubes may be used for demonstration. Of these cubes, there were two series, with 12 lots of 8 cubes each in each of the two series. The different compositions of the 12 lots in each series were the same, and also were such that the rate of dehydration was expected to be progressively slower from the most to the least rapid. The two series were tested separately and under identical circumstances. The result, in the form of ranks, is given in Table I.

TABLE I—RANKED RATES OF DEHYDRATION FOR BIOCOLLOIDAL CUBES*

Sets of cubes	a	b	c	d	e	f	g	h	i	j	k	l
Rank—1st test	1	2	3	4	5	6	7	8	9	10	11	12
Rank—2nd test	2	1	3	5	4	7	6	10	8	9	12	11
Deviation	−1	+1	0	−1	+1	−1	+1	−2	+1	+1	−1	+1
Sq. of deviation	1	1	–	1	1	1	1	4	1	1	1	1

*Based on average weights of lots, when lot "a" had reached constant weight.

The formula for rank correlation, as derived by Pearson (1), is: $\rho = 1 - \frac{6\ \Sigma(d^2)}{n\ (n^2-1)}$, in which "n" is the number of ranked pairs and "d" is the difference between the ranks in a pair. This, for the data in Table I, becomes:

$$\rho = 1 - \frac{(6)\ (14)}{(12)\ (143)} = 0.951 \pm 0.020.$$

The probable error of this coefficient was obtained by the use of Pearson's formula (1), which is:

$$\text{P. E. } \rho = \frac{0.6745\ (1-\rho^2)}{\sqrt{N}}\ (1 + .806\ \rho^2 + .013\ \rho^4 + .002\ \rho^6).$$

With the actual values (weights) of the variates of Table I in hand, the usual coefficient of linear correlation may be calculated for the

purpose of comparison. It comes to be 0.935±0.024. This obviously, is essentially identical with the coefficient of rank correlation for the data on the biocolloidal cubes.

The greater ease and speed with which the rank coefficient can be calculated, as compared with "r", has been mentioned. It's special merit, however, is the possibility of its use in cases where truly quantitative measurements are not obtainable, and hence, the values of the variates can not be expressed in cardinal numbers.

An example for demonstration can be that of a result from the effort of a member of a so-called "tasting squad", with respect to the sampling of "frozen-pack" fruit. The usual procedure in this is to set out a number of samples which vary in some single respect, and have them graded by one to several persons, or tasters. An arbitrary scale of, say, one to nine points is adopted. The taster uses this scale on the estimation of each of several properties (color, flavor, texture, aroma, and so on) for each sample, and at the end, these estimations are averaged and the sample is rated accordingly in its quality. This having been done for each sample, the alignment of the several samples, in the order of their quality, is accomplished.

How substantial and reliable is this procedure? Obviously, it is far from being truly objective and quantitative. One manner of approach is to determine, if possible, the sensitivity and accuracy of the taster's "taster". This can be done by having him repeat the test, with the order of placement of the samples secretly and completely changed, and then correlate his two trials.

For this, the ordinary process of linear correlation cannot be employed, since the values for the variates are not in terms of any unit for objective measurement. Assuming, however, that if the actual measurements were attainable they would have a normal, or nearly normal, frequency distribution, the way is open to proceed with the technique of correlation from ranks.

Table II gives, for demonstration, the result from a duplicated test for one of the tasters in a sampling of "frozen-pack" sweet cherries, when the value of "n" was 10.

The coefficient of correlation from ranks for the data of Table II is 0.775±0.133. Obviously, it is fully significant. The efficiency of this particular taster, in this instance, was high. An extensive use has been made of the technique of rank correlation for testing the reliability of the so-called organo-leptic method for the estimation of quality in packed fruits. The outcome will be reported soon in some one of the national journals for research.

The transformation of the coefficient of rank correlation into that

TABLE II—Correlation from Ranks for "Frozen-Pack" Sour Cherries

Samples	A	B	C	D	E	F	G	H	I	J
Rank—1st test	1	1	3	4	5	6	7	8	8	10
Rank—2nd test	3	2	5	4	6	1	6	8	9	10
Deviation	−2	−1	−2	0	−1	+5	+1	0	−1	0
Squares	4	1	4	0	1	25	1	0	1	0

of ordinary linear correlation is easily accomplished. The formula, given by Pearson (1), is as follows: $r = 2 \sin (\pi/6\rho)$. The application of this formula to the coefficient (0.775) for Table II gives 0.784 as the corresponding value for "r".

The value of "n" in this case is small, being but 10. This being true the significance of "r" is better determined by transforming it into either a "t" or else a "z" value through the use of Fisher's procedures for small samples. The formula for the "t" transformation is: $t = \frac{r}{\sqrt{1-r^2}} \cdot \sqrt{n^1-2.}$ The value here for "t" is then 3.572. This value exceeds even the 1 per cent level,—indicating unquestionable significance for the coefficient (0.784) obtained. And when "n" is small, it is better, really necessary, to convert "ρ" into "r" in order correctly to arrive at its significance.

In general the two coefficients (ρ and r) are closely the same. However, since the value of "r" is conditioned by the magnitudes of the actual values of the variates and "ρ" by only their orders of rank, the two, in unique instances, may be widely apart. An example of this can be the following arbitrary series, in which "ρ" is 1, or perfect, whereas "r" is far from being equal to unity.

x: 80, 70, 60, 50, 30
Y: 150, 145, 90, 4, 1

The occurence of ties in ranking is apparent in Table II. Two ways exist for handling this situation. One of these is the bracket method, which is used here. Each item in the set of ties is given the same rank, this rank being one unit above the rank immediately preceding the group. The rank first following the group is then taken as though the ties had not intervened in the succession of consecutive numbers.

The second way for handling ties is the mid-rank method. In this procedure the ranks are formed so that their sum $[n (n + 1)/2]$ is the same as though no ties had occurred. For example, take "H" and "I" in the top rank of Table II. Without this tie these two figures would be 8 and 9, and their sum would be 17. Therefore, instead of 8, each would be given the value of 8.5, according to the mid-rank method. It is obvious that when ties exist, and whatever the manner of their adjustment, the coefficient is not exactly correct. Its inexactness, however, is slight, and it is considered as being sufficiently correct.

Finally then, it is permissable to suggest the use of the coefficient of correlation from ranks when (a) with the actual values of the variates at hand, it will give, with greater ease and speed, all the information desired, and when (b) with the actual values of the variates missing, perhaps unattainable, it will give enough information to be decidedly helpful.

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Comparative Earliness and Productiveness of First and Second Generation Summer Squash (Cucurbita Pepo) and the Possibilities of Using the Second Generation Seed for Commercial Planting

By LAWRENCE C. CURTIS, *Connecticut Agricultural Experiment Station, New Haven, Conn.*

IN 1939 the author (1) reported on the expression of heterosis in the first generation hybrid between two lines of summer squash and the possibilities of producing the first generation hybrid seed for commercial planting. The results presented in this paper are derived from the continuation of that study.

In 1940 the two parents, the first and second generation hybrid and a commercial variety, were planted in a picking trial arranged in a 5 by 5 Latin square. Each block consisted of 60 plants, three rows of 20 plants each, spaced 6 by 2 feet. One planting was made at Mount Carmel, Connecticut, on June 8, and another at Windsor, Connecticut, on July 5. The first picking was made at Mount Carmel on July 23 and at Windsor on August 20. Pickings were continued at two day intervals for the duration of the season. Individual plant records were kept on numbers of fruit produced and at Mount Carmel weight per fruit per plant was recorded from the beginning of the season to August 11.

The pickings up to and including July 27 were arbitrarily classified as early fruit at Mount Carmel and at Windsor, August 29 was chosen as the limiting date. The data were analyzed by the analysis of variance method as described by Yates (2). In this case Giant Summer Straightneck was not included in the analysis.

According to Table I there is no significant difference between the F_1 and F_2 either in early or total fruit except for early fruit at Windsor. This difference has a P value between the .01 and .05 point. The early production of fruit on the F_2 at Windsor is however significantly higher than Early Prolific Straightneck, the earliest and most productive commercial variety available. The question is asked then, why cannot the second generation be used for commercial planting?

Such a suggestion is contrary to the practice with corn which is at present the only crop of which hybrid seed is produced and sold on a

TABLE I—YIELD OF SQUASH AT MOUNT CARMEL AND WINDSOR, CONNECTICUT (1940)

Variety	Early Fruit		Total Fruit	
	Mt. Carmel	Windsor	Mt. Carmel	Windsor
Early Prolific Straightneck (P)	240**	164**	3116	2384
Connecticut Inbred (C10)	190**	234**	2162**	1716**
C10×P F_1	405	483	2921	2514
(C10×P)a F_2	417	357†	2898	2243
Giant Summer Straightneck*	0	5	1934	1582

*Not included in the analysis of variance.
**Significantly different from F_1 at .01 point.
†Significantly different from F_1 at .05 point.

commercial basis. With this crop the total yield of the second generation is reduced and extremely variable.

With this particular hybrid squash, however, neither the total yield nor the earliness of yield is materially reduced in the second generation and as to variability, summer squash is usually harvested in an immature stage so that the size and, to a lesser degree, the shape of the fruit is determined by the time of picking.

The advantage of the second generation over the first is in the cost of the production of seed. When the expense of emasculating female rows in a crossing plot and the care that accompanies the production of first generation seed can both be eliminated, then this advantage assumes commercial importance.

From these results it is apparent that the possibility of using second generation seed with other vegetables is worthy of consideration. Heretofore the expense and the technical difficulties of producing first generation seed for commercial plantings have been prohibitive for most vegetable crops.

A logical argument against the use of second generation seed may be based on the fact that the maximum amount of segregation occurs in this generation. It must be remembered, however, that hybrids which have demonstrated heterosis have been derived in most cases from parents which are extreme in color, shape and size of fruit as well as growth factors. When these extreme parental types together with their various combinations reappear in the second generation, the resulting crop is naturally too variable to be sold.

If hybrids can be produced by crossing inbreds or varieties which are similar both in plant type and in color, shape and size of fruit but sufficiently different in growth factors to produce heterosis, then the extreme variations which normally appear in the second generation may be reduced. We should look for inbreds which produce better second, rather than first generation hybrids.

Possibly the use of second generation seed may be limited to those crops having an indeterminate growth in which the fruit is harvested in an immature state such as cucumbers and peppers or is graded as mature fruit such as tomatoes.

According to Table II there is another advantage of the second over the first generation. It will be seen that 2.4 per cent of the plants of the second generation produced female blossoms two days before the first female blossom opened on the first generation. It appears that there

TABLE II—NUMBER OF SQUASH PLANTS PRODUCING THEIR FIRST FEMALE BLOSSOMS FROM JULY 13 TO 22, 1940, AT MOUNT CARMEL

	13	14	15	16	17	18	19	20	21	22	Total	No. of Plants	Per Cent
P	0	0	0	0	0	0	0	0	0	203	203	284	71.5
C10	0	0	0	0	0	0	0	0	0	140	140	261	53.6
10×P	0	1	8	15	22	43	8	13	138	2	250	286	87.4
(10×P)a	7	1	9	31	21	31	10	21	128	5	264	292	90.4

Accumulated Percentages of Plants Showing First Open Female Blossom on (10×P)F_1 and (10×P)a F_2

	13	14	15	16	17	18	19	20	21	22	Total	No. of Plants	Per Cent
10×P	—	.35	3.15	8.4	16.	31.1	33.9	38.5	86.7	87.4			
10×Pa	2.4	2.7	5.8	16.4	23.6	34.2	37.6	44.8	88.7	90.4			

is in the second generation segregation for earliness. This spread in variability instead of being a disadvantage may be particularly valuable where special qualities such as earliness may be accentuated.

Segregation for earliness is also an advantage to the market gardener who would prefer to have the plants come gradually into bearing rather than to have them all begin to bear on the same day.

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The Value of Native Material in Breeding Horticultural Crops for Alabama[1]

By C. L. ISBELL, *Alabama Agricultural Experiment Station, Auburn, Ala.*

IT IS known that some seedling apple, pear, and various nut trees in Alabama produce large crops of good quality with very little attention, and many Alabama farmers depend entirely on these seedlings for their supply of fruits and nuts. The Alabama Experiment Station is collecting and testing the most desirable of these seedlings for use in establishing varieties better adapted to Alabama conditions.

FRUITS

An example of the value of native material is shown by the results obtained from a variety trial with grapes at Auburn. Three vines each of 50 standard varieties of bunch grapes, some of which are of wild parentage and one to two vines each of six different selections of wild grapes from North Alabama were planted in 1919. Two to three vines of the varieties having wild parentage, namely, Champanel, Herbemont, Lukfata, Manito, Sabinal, and Salamander are alive and appear able to produce good yields for many more years. Plants of other named varieties have all died. The wild plants are all alive and fruiting well. Some of these native plants when grown in North Alabama retain the fruit in edible condition until after Christmas. Grapes harvested December 12, 1938, from one of the wild vines at Auburn illustrate this characteristic (Fig. 1A). The individual grapes were shriveled or dried like raisins and some had shattered; slightly more than 85 per cent of the berries remaining on the bunches were sound and edible. These wild grapes should be used to develop varieties that would extend the fresh-grape season.

Highbush and lowbush blueberries, often referred to as huckleberries, grow wild in Alabama. In the communities where available in quantity, they are used for home consumption and are of some value commercially. Studies started in 1925 with plants of the highbush type selected from the swamps, and more recently with plants of the lowbush type collected from the upland sections of eastern Alabama show that each of these types differs widely in size, color and fruitfulness and that the berries produced by different plants vary much in date of maturity, size and quality. The most promising plants are being propagated and studied to determine their value in breeding better varieties.

Plantings of standard varieties of sour cherries at Auburn have been complete failures. Most of the sour cherries grown in North Alabama and all of those grown in middle Alabama are unnamed strains that have developed as sprouts on lateral roots of parent plants. There are a few of these native cherry trees in the vicinity of Auburn that have been fruiting 35 to 45 years without any special care (Fig. 1B).

[1]Native material as referred to in this paper includes indigenous plants and named and unnamed varieties or strains that have been grown long enough in the South to establish the fact that they are well adapted to southern conditions.

FIG. 1. A, Native grapes with more than 85 per cent of the remaining berries sound when harvested December 12, 1938. B, The native cherry tree shown on the right is about 50 years old. It has been fruiting in Auburn, Alabama, for more than 45 years. Young trees to the left and in the foreground are volunteer plants from lateral roots of the parent. They fruit well like the parent. C, Semi-vining wax podded snap beans. D, Mature plant of semi-vining green podded snap bean.

Sprouts from these plants are being used to determine whether desirable varieties may be developed.

NUTS

Yield records and nuts obtained from seedling pecan trees throughout the state indicate that there are seedlings that produce more nuts of better quality than some of the named varieties now growing in Alabama. These seedlings are being collected, propagated and tested.

Seedling black walnuts are of considerable importance for home use in Alabama and many farmers grow one or more seedling walnut trees regardless of their fruitfulness or the quality of the nuts they produce. A few trees of some of the varieties that originated farther north are fruiting in Alabama. To determine the quality of nuts produced by seedling trees as compared with standard variety and to locate the best seedlings for use in developing better varieties for Alabama, nuts were collected in 1934 and 1935 from 18 seedling black walnut trees growing in various sections of Alabama and from a named variety, Thomas, growing in east Alabama. Results obtained from cracking and shelling these nuts showed a wide variation in the quality of the nuts produced by the different trees.

The weight of 100 hulled and dried nuts ranged from a minimum of 2.93 to a maximum of 7.16 pounds. The number of whole quarters obtained from 100 nuts ranged from 20 to 360. The weight of the kernels obtained from 100 nuts ranged from 0.45 to 1.53 pounds and the per cent of the kernels based on the weight of the hulled nuts ranged from 12.5 to 24.7. Nuts from five of the seedlings were larger than the nuts of the Thomas variety. Nuts from five of the seedlings shelled out more quarters per nut than the Thomas and four of the seedlings produced a greater kernel weight per hundred nuts than Thomas. Eight of the seedlings yielded a greater percentage of kernel based on the weight of hulled nuts than that produced by the Thomas. Buds from one of the seedlings were placed about 6 inches from the ground in a seedling black walnut stock 1½ inches in diameter in mid-summer of 1936. The budded tree produced 17 nuts in 1938 and has borne nuts each year since.

These results show that there is a wide variation in the relative value of existing seedling black walnuts in Alabama and that there are seedling black walnuts in Alabama that compare favorably with one of the best named varieties developed elsewhere, indicating the possibility of the development of southern varieties from native material.

Vegetables

Most varieties of vegetables have been developed for sections other than the South. Such varieties are generally not capable of producing good yields of vegetables of high quality under weather conditions which occur in the South. Furthermore, they do not possess enough immunity, resistance or tolerance to important insects, diseases, and other pests so common in the section. Therefore, necessity has encouraged a few farmers to save vegetable seed from varieties that have done best and gradually over the years certain strains have become well adapted by the survival of those most hardy to southern conditions. There are a considerable number of strains of vegetables in Alabama that have proved to be adapted to southern conditions and the Experiment Station is collecting and using them as foundation stock for developing varieties.

The Alabama Experiment Station has already made an important contribution in this field. Pole snap beans of good quality, that are resistant to root knot caused by nematodes and fruit well during the dry weather of summer and early fall have been introduced. Other strains of pole snap beans well adapted to certain sections of the state are being tested and improved. One white-seeded strain appears promising as a green snap bean and as a dry shell bean for boiling or baking.

Semi-vining strains of both wax and green podded snap beans have been collected and tested (Figs. 1C and 1D). Most of these strains are rather susceptible to mosaic, but they yield very well. They may be used as a substitute for pole varieties by those who consider the labor of staking important enough to accept a bean of somewhat less quality that does not require staking. Strains of semi-vining habit are available with white seed and with various other seed colors. The

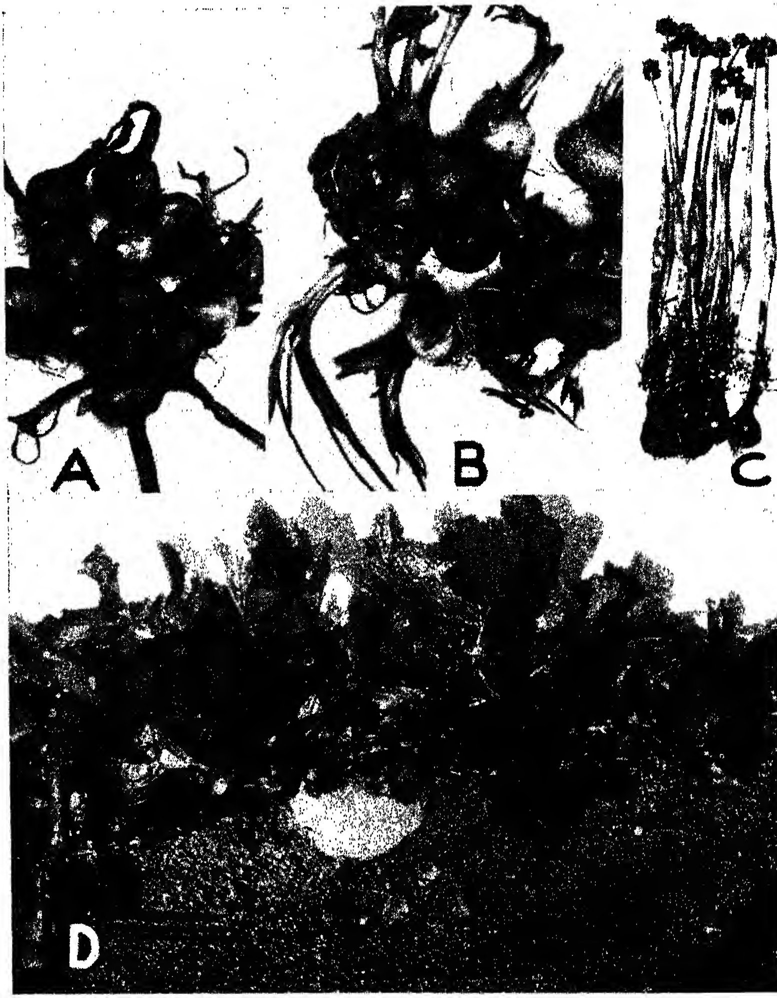

FIG. 2. A, A winter hardy American type of onion. Selected in North Alabama; grown and stored under similar conditions as B, Yellow Bermuda. Photo December 1, 1938. C, A winter hardy onion that will supply green onions for 8 months of the year and that stores well. Selected in Central Alabama. D, Local strain of turnip collected in North Alabama that develops well below the surface of the ground where it is well protected against freezes.

white-seeded strain is popular with some growers because it may be used for snap beans or for dry or baked beans.

Three strains of onions that withstand low temperature and store very well have been collected. Two of these are considered of value as dry onions for general use. One of these strains is shown (Fig. 2A) contrasted with Yellow Bermuda (Fig. 2B). Succession plantings of

the other, a multiplier type, will supply green onions for about 8 months of the year. It will also supply small onions that may be dried and stored in common storage for 8 to 10 months for flavoring purposes (Fig. 2C).

Observations at Auburn show that the table varieties of cowpeas vary greatly in their susceptibility to root troubles and that the extent and the nature of the development of the root system also varies greatly. These differences determine the ability of a variety to succeed in a given locality. For example, the Conch and the Purple Hull (white-seeded) varieties and a local strain have deep penetrating root systems that are not seriously injured by nematodes and root diseases. These usually live and fruit over a longer season than the California Black Eye which has a very limited root system. Under favorable soil conditions, most of the Crowder varieties produce a well developed root system capable of supporting the plants over a long season, but heavy nematode infestation injures the root system to the extent that many of the plants die before they attain fruiting age. A selected strain of the Lady variety produces peas almost twice as large as those commonly produced by this variety. The new strain is so susceptible to nematodes and southern blight (*Sclerotium rolfsii*) that very few plants reach the fruiting stage. This shows that it is useless to introduce a new variety of table cowpea for general use in Alabama, regardless of the quality of the pea, unless the variety has a satisfactory root system for the locality in which it is to be grown.

A reseeding, bronze, loose leaf, butter type of lettuce which has been selected is showing much promise as a winter-hardy lettuce. This strain should be of considerable value to home gardens in Alabama, as standard varieties of lettuce require some winter protection, and most farmers do not attempt to protect lettuce during the winter.

As catalogued varieties of fall planted turnips in the northern part of Alabama are not winter hardy, a variety that would develop an edible root well below the surface of the ground where it would not be ruined by freezing and a top hardy to freezes would be a valuable addition to the home supply of vegetables during the winter months. Strains have been collected in two communities in North Alabama that have done well in these respects for many years (Fig. 2D). These are being tested and appear to have promise.

Most sections of Alabama grow good local strains of red-fleshed watermelons, some of which date back as far as 1865. In addition to these red-fleshed selections, several types of orange-fleshed varieties have been collected and grown at Auburn. Each of the orange-fleshed selections is of much better quality than any catalogued variety of orange-fleshed watermelon that has been tested at the Experiment Station.

Summary

Native horticultural plant materials consisting of fruits, nuts, and vegetables are being collected from various parts of Alabama and tested to determine their merits in their present form and also tested to determine their possible use in developing better varieties of horticultural crops for Alabama.

The quantity of plant materials located and collected as the result of a limited scouting program is proof that there is an abundance of such material available.

The relative merits of samples collected differed greatly. Some strains were found to be so poor in quality, yield, or general adaptation that they are of little value in their present form and do not appear to be promising sources of plant breeding material. Other strains were found to be valuable in their present form because of quality, yield, and general adaptation.

The results obtained by the use of the best native material show that such strains often possess more desirable qualities for a given locality than do named varieties. The best native material was found to be valuable in developing better varieties for Alabama conditions.

Corn Earworm Resistance and Plant Characters[1]

By CHARLES F. POOLE, *U. S. Department of Agriculture, Charleston, S. C.*

NUMEROUS studies of the reaction to corn earworm, *Heliothis armigera* Hbn., of commercial sweet corns and southern field varieties have established statistically significant differences between varieties. Variety tests made in such widely separated regions as Davis, California (4), Winterhaven, Texas (2, 3), and Charleston, South Carolina (5) show that the more resistant field corns and susceptible sweet corns exhibit the same order of response over a wide territory and from year to year. Backcross populations of F_1 hybrids to both kinds of parents showed pronounced differences in resistance to worm damage (4).

The more resistant varieties mature later than the more susceptible ones, but variance analysis showed that different time of maturity had no effect on the order of earworm resistance in five varieties possessing extreme ranges in resistance (4).

In 1917 Collins and Kempton (1) studied earworm resistance among the progeny of a series of crosses between dent and sweet varieties. Statistical treatment for inter and intra progeny measurements indicated that the increased resistance of the hybrids was probably due to characters not measured, but correlated with husk extension beyond the eartip. They suggested the presence of some volatile substances distasteful to the moth or larva, but too elusive for measurement.

The search for morphological characters associated with earworm resistance is important because the breeder could self-pollinate a plant possessing those characters and readily establish a highly resistant inbred line. Lacking such a character it is necessary to select protected self-pollinated ears of unknown type from lines whose unprotected open-pollinated ears indicate promise of resistance. The method will eventually produce homozygous inbred lines, but the degree of earworm resistance obtained depends on the chance inclusion of as many as possible of the genes for resistance that were present before selection began.

MATERIALS AND METHODS

Study of the causes of earworm resistance was made from measurements taken at Davis, California, in the summers of 1934 and 1935. Quantitative estimation of earworm resistance was made by a resistance index reached by classifying ears on a five point scale: 5, no damage; 4, damage in silks only; 3, in tips only; 2, slightly beyond the tip; 1, unmarketable. In 1934 simple correlation coefficients were computed from data on 34 varieties, involving the five variables: resistance index, extension of the husk, ear length, days to first silking, and plant height. In 1935 a more thorough study of the factors influencing insect damage was made from two four-replicate random-

[1]Contribution No. 6 from U. S. Vegetable Breeding Laboratory, Charleston, S. C.

ized block experiments with 12 varieties and 17 hybrids between commercial varieties. On this occasion the foregoing five variables were increased to seven by the addition of ear weight and number of husks, and correlation was calculated by the covariance method of Snedecor (6) applied to all 21 combinations shown as from total, between-variety, and within-variety sources.

Morphological Characters and Earworm Resistance

Measurements taken on 34 varieties of sweet and field corn grown in 1934, and on 12 varieties and 17 hybrids between sweet and starchy varieties grown in 1935, were analyzed for possible relationships between earworm resistance and several morphological characters. Intravariety correlation coefficients were computed for each variety for earworm resistance vs. husk extension, for earworm resistance vs. ear length, and for earworm resistance vs. number of husks, and the correlation between husk extension and number of husks was determined. For earworm resistance vs. husk extension only six varieties exhibited a coefficient which was significant at the 5-per cent point, and in three of these the same variety failed to show significance in both the years represented. In the case of earworm resistance vs. ear length only two varieties exhibited significant coefficients at the 5 per cent level, and one was negative whereas the other was positive. No varieties indicated significant intravarietal correlations for either number of husks with earworm resistance, or number of husks with length of husk extension.

Zero order correlation coefficients were computed in the 10 possible between-variety combinations for the following variables: earworm resistance, husk extension, ear length, time elapsed from planting to silking, and plant height. These data indicated that between varieties earworm resistance is significantly correlated with all the characters *except* husk extension, that husk extension fails to be correlated with any of the others, and that all the others are correlated *inter se*.

In order to learn if a possible correlation between earworm resistance and husk extension was masked by the simultaneous interaction of the independent variables ear length, days to first silk, and plant

TABLE I—Intervariety Coefficients of Partial Correlation Between Resistance Index and Husk Extension Independent of Ear Length, Days to First Silk, and Plant Height

Zero-Order Partial Correlations	Independent Variables		
	Ear Length C	Days to First Silk D	Plant Height E
Resistance index and husk extension AB	0.25	0.07	0.21
First-order partial correlations	Ear length and days to first silk CD	Ear length and plant height CE	Days to first silk and plant height DE
Resistance index and husk extension AB	0.14	0.21	0.20
Second-order partial correlations	Ear length, days to first silk, and plant height CDE		
Resistance index and husk extension AB	0.22		

height, first and second order partial correlation coefficients were calculated. Table I shows that under conditions where 0.35 is required for significance at the 5 per cent level no coefficient above 0.25 was obtained regardless of the number of independent variables.

Analysis of 1935 Data

The four variables studied in 1934 for possible correlation with earworm resistance were increased in 1935 to six by the addition of number of husks per ear and weight of ears. Correlation between varieties, as well as that within varieties, is calculated by covariance analysis. For this purpose we have data for 21 combinations between seven variables for data measured from two 1935 experiments, the first containing 12 varieties, and the second containing 17 variety hybrids, each experiment appearing in four replicates.

The correlation coefficients for the 12 varieties are shown in Table II and those for the 17 variety hybrids are shown in Table III. Coefficients for between-variety and total sources are found in the cells of the upper right triangular part of each table, and the coefficients for within-variety sources in the lower left triangle.

Table II shows that for the 12 varieties the only significant coefficients for earworm resistance vs. each of the other variables occurs for between-variety sources and for total sources (including between-variety sources) but never for within-variety sources. Significant coefficients are obtained for the variables: elapsed time to tasseling, height, and number of husks; but not for ear length. In Table III

TABLE II—Correlation Coefficients from 21 Combinations Obtained by Covariance Analysis for Seven Variables in Twelve Varieties, 1935 (Total and Between-Variety Source Coefficients, Upper Right Triangle; Within-Variety Source Coefficients, Lower Left Triangle)

Characters Compared	Resistance Index	Extension of Husk	Elapsed Time to Tassel	Plant Height	Ear Weight	Ear Length	No. of Husks
Resistance index		0.189 .190	0.670† .503	0.631† .792†	−0.235 − .299	0.088 .123	0.623† .737†
Extension of husk	0.187		.266 .342	.029 .036	− .214 − .238	−.281 −.232	.088 .123
Elapsed time to tassel	−.136	−.228		.929† .949†	− .010 − .012	.204 .210	.903† .676†
Plant height	−.198	−.001	.400*		.025 .070	.427† .419	.629† .652*
Ear weight	0	−.134	−.020	.019		.499* .476	.044 .047
Ear length	−.072	− .539†	.195	.566†	.665†		.100 0.100
No. of husks	0.095	−0.150	0.485†	0.135	0.015	0.100	

Significance levels:	5 Per Cent	1 Per Cent
Total sources	0.288	0.372
Between varieties	.576	.708
Within varieties	0.325	0.418

*Significant coefficients at 5 per cent level.
†Significant coefficients at 1 per cent level.

TABLE III—CORRELATION COEFFICIENTS FROM 21 COMBINATIONS OBTAINED BY COVARIANCE ANALYSIS FOR SEVEN VARIABLES IN SEVENTEEN F_1 HYBRIDS BETWEEN COMMERCIAL VARIETIES, 1935 (TOTAL AND BETWEEN-HYBRID COEFFICIENTS, UPPER RIGHT TRIANGLE; WITHIN-HYBRID COEFFICIENTS, LOWER LEFT TRIANGLE)

Characters Compared	Resistance Index	Extension of Husk	Elapsed Time to Tassel	Plant Height	Ear Weight	Ear Length	No. of Husks
Resistance index		0.141 .113	0.115 .160	−0.050 − .075	0.035 .037	0.212 .359	0.061 .101
Extension of husk	0.208		.060 .082	.007 .024	−.332† −.340	−.369† −.346	.113 .182
Elapsed time to tassel	.051	.030		.651† .775†	.091 .121	.193 .278	.492† .602*
Plant height	−.013	.080	.061		.117 .131	.082 .085	.590† .665†
Ear weight	−.134	−.307*	−.081	.063		.767† .786†	−.054 −.123
Ear length	.011	−.328*	−.216	−.036	.715†		−.033 −.160
Number of husks	0.011	0.204	−0.038	0.056	0.258	0.674†	

Significant levels:	5 Per Cent	1 Per Cent
Total sources	0.232	0.302
Between varieties	.482	.606
Within varieties	0.273	0.354

*Significant coefficients at 5 per cent level.
†Significant coefficients at 1 per cent level.

there are no significant correlation coefficients from any sources of variance when resistance index is compared with the remaining six variables. Other coefficients are not pertinent to our present problem and may be omitted from consideration.

DISCUSSION

No evidence presented here tends to support the widely held belief that a long husk extension or a heavy husk covering confers high degrees of earworm resistance. The lack of correlation of any of the six morphological characters with earworm resistance, first obtained by crude methods in the 1934 study, is verified and extended with the more refined methods used with the data of 1935. Some question on the validity of inferring significant degrees of correlation arises when only 10 or 15 degrees of freedom between varieties are available, because significance at the 5 per cent point is only implied when the calculated coefficients exceed .6 and .5 respectively. This question does not arise in the present instance, however, since none of the calculated coefficients involving earworm resistance within varieties exceeds .3 and no significance is even suspected.

The analysis of variance and covariance shows that the tests themselves are statistically significant, and that no correlation coefficients involving earworm resistance are significant within-varieties or between- and within-hybrids. In interpreting these data it is assumed that the only significant correlations which would have a real bearing on this problem would be those within-varieties and within-hybrid

progenies. The statistically significant correlation coefficients from between-variety sources probably resulted from the fact that the majority of the varieties used for introducing earworm resistant genes possessed those combinations by chance.

Practically all the resistant varieties of corn tested in 1934 and 1935 are southern dent varieties, or varieties developed by cross pollination between northern sweet corns and southern dent corns. The latter varieties are tall, many husked, comparatively late-maturing descendants of types adapted through continued cultivation from pre-Columbian times in regions where the corn earworm thrives in all seasons. In the course of time this combination of characteristics has come to be a regular feature of all or most subtropical or tropical corns. Probably the association is one of coincidence rather than genetic relationship.

On the other hand, the sweet corns of the north were developed quite recently in regions where the corn earworm is seldom a factor in corn cultivation, and where early maturity is necessary. Consequently we have an association of earliness, shortness, and either susceptibility or resistance to the corn earworm. The inclusion in one test of varieties most of which are of southern origin gives the unjustified impression in some cases of significant correlation between those quantitative characters and earworm resistance. When we eliminate the between-variety variance, however, the true nature of that relationship is uncovered.

Study of intravariety correlation between length of husk extension and resistance index for 1934 showed that six out of 34 varieties had significant coefficients. In 1935 two of these six varieties failed to show intravariety significance, and the one variety out of 12 which in 1935 showed intervariety significance was non-significant in 1934.

The studies indicate that no morphological character yet measured is signicantly correlated with earworm resistance. A likely field for investigating the factors conferring resistance is biochemical search for volatile compounds.

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A Colchicine-Induced Homozygous Tomato Obtained Through Doubling Clonal Haploids[1]

By Earl H. Newcomer, *Michigan State College, East Lansing, Mich.*

IN THE several years which have elapsed since the introduction of colchicine, there have been numerous reports of its successful use in the induction of polyploidy in plants. The literature on the subject has just recently been reviewed by Dermen (1).

It is too soon, perhaps, to attempt to evaluate the significance of the colchicine technic, since time has only permitted the publication of reports of its successful use on the shorter cycled plants. As new technics are developed for its use on a wider range of plants, especially the woody types, its present value as an aid to the plant breeder may be demonstrated to have been only a potential one.

Horticulturally, the most promising of the colchicine-induced tetraploids produced to date appear to be the marigolds and snapdragons of Ruttle and Nebel (5), the lilies of Emsweller and Brierley (2), and the white cosmos produced here (4).

In addition to the production of desirable phenotypic characters through polyploidy, colchicine may also prove useful in the securing of genetic homozygosity in a single generation where haploid plants are available, thus eliminating the time and effort usually required by generations of inbreeding.

Materials and Methods

In this study, cuttings from five tomato plants (var. Supreme Marglobe) were selected from the field of the Ferry Morse Seed Company as being possible haploids on the basis of dwarfness, short internodal length, smaller leaves and flowers. Subsequent cytological examination proved that two of them were haploid (Fig. 1, A, B, C) and that the remaining three were "rogues" with a diploid chromosome complement. The two haploid plants were rooted and 18 more plants propagated from them by cuttings, and subsequently all but two were treated with colchicine. The technic used was the one originated by Warmke and Blakeslee (6), which is superior to the usual aqueous solutions or lanolin mixtures. The formula for the emulsion is as follows:

Stearic acid	3.00 grams
Morpholine	1.06 cubic centimeters
Tap water	40.00 cubic centimeters
Lanolin	16.00 grams

Add water to stearic acid and morpholine and heat mixture until stearic acid is melted. Stir to a creamy soap solution. Add lanolin and continue heating until the lanolin is melted and the mixture is just below the boiling point. Stir to an emulsion and continue stirring intermittently until the emulsion is cooled to room temperature.

The emulsion must be diluted for spraying. Dilute by adding four

[1]Journal Article No. 497, N. S., of the Michigan State College Experiment Station.

parts of water to one of emulsion. The colchicine is then added to the desired concentration. This emulsion is very stable if kept in a cool place.

Observations

The usual concentrations of colchicine vary between 0.1 and 0.8 per cent. A 0.4 per cent solution was effective on the tomato, and two of the 18 treated plants successfully responded to produce homozygous haploid gametes and normal fruit. All the plants treated became hypertrophied, producing thickened, misshapen leaves and stem tissue, but in only two instances were more than the peripheral tissues affected. The plants, after alternate daily treatment with colchicine pipetted or sprayed on the growing shoot tips until the cessation of growth and the beginning of hypertrophy, were transplanted to the field for maturation. With the appearance of flower buds, cytological examination of the chromosomes was made and two of the plants proved to be diploid (Fig. 1, D). Frost arrived before most of the fruit was mature, but enough ripe fruit was collected for seed. Further studies on the progeny of this homozygous line will be made to determine whether it has any practical advantages such as greater uniformity of fruit or other characters.

The cytology of the haploid tomato has been described by Lindstrom (3), and nothing new was observed here to add to his account. There is frequently a congression of the univalent chromosomes on the equator at the first metaphase (Fig. 1, B) followed shortly by an erratic and often rather aimless separation (Fig. 1, C) with frequent laggards. Only abortive gametes were ever observed.

The chromosome behavior of the derivative diploid plants appeared to be normal in every respect (Fig. 1, D).

Summary

Of five plants selected in the field as haploids on the basis of phenotypic characteristics, two were haploid and three were diploid "rogues". The two haploids were multiplied by cuttings and 18 of them were treated with a 0.4 per cent colchicine emulsion. All treated plants became hypertrophied, but in only two was the response more than superficial. These two plants, by cytological observation, proved to be diploid and produced a

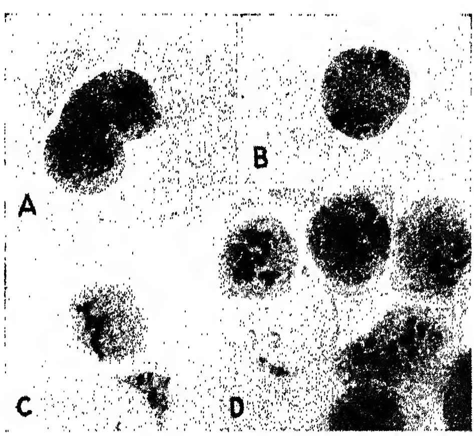

Fig. 1. A, B, C, The twelve univalent chromosomes of the haploid tomato at diakinesis, metaphase and telophase respectively. D, The twelve bivalent chromosomes of the colchicine—induced diploid tomato.

crop of normal fruit. No new observations were made on the cytology of the haploid.

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Fertilizer Placement with Respect to Location and Time in the Production of Cauliflower on Long Island[1]

By W. C. Jacob and R. H. White-Stevens, *Cornell University, Ithaca, N. Y.*

Abstract

This material will be incorporated in a publication from Cornell University.

THE results of 3 years' study, using factorial experiments, of the placement of fertilizer for cauliflower on Long Island showed that for Long Island conditions broadcasting the large quantities usually used will give superior yields to band placement of these amounts. If a benefit is derived from band placement, the amount of fertilizer being applied is probably too small and larger yields would be obtained by broadcasting larger quantities of material. Side dressing with nitrate of soda is beneficial even when as much as a ton of 4–8–6 analysis fertilizer is applied.

[1]Conducted in cooperation with the United States Department of Agriculture, Bureau of Agricultural Engineering, Washington, D. C. The authors wish to express their appreciation to the members of this staff for the use of their machinery and their kind supervision in its operation.

The Relation of Yield of Staminate and Pistillate Asparagus Plants to the Rate of Growth of Progenies in the Young Stage[1]

By A. L. Richardson, *North Central Experiment Station, Grand Rapids, Minn.*, and T. M. Currence, *University of Minnesota, St. Paul, Minn.*

In the improvement of a dioecious crop such as asparagus there are a number of problems which are not generally found in plant breeding. Whether or not parental vigor is transmitted to progenies has not been reported in the literature. Likewise, there is no information as to the relative importance of pistillate and staminate parents on progenies. Work by Currence and Richardson (1), although not extensive, suggests that the progeny test would be most effective in identifying exceptional parental material. In an effort to simplify and hasten the procedure in making such tests, records have been taken on the early development of several strains resulting from different combinations of three female and six male plants.

In relation to asparagus breeding such a test of young material would be very useful if future results indicate a definite relation between the rate of growth of seedlings and their later production under field conditions.

Materials and Methods

Parent plants were selected on the basis of their vigor or lack of vigor as indicated by 3-year records on weight, yield, number of spears per plant, and average weight of individual spears. Seeds of 18 combinations of three female and six male plants were obtained, and 50 of each were planted individually in 1½ inch pots which were arranged in two series. Dates of germination were recorded daily, thereby giving records on the number of days between planting and germination for each individual. Two and one-half months after seeding, the plants were carefully removed from the pots, washed and weighed. They were then repotted in 4-inch pots. Four months later, they were again weighed.

Comparison of Pistillate and Staminate Parents

The annual means of the measurements of the pistillate parents are

TABLE I—The Number of Spears, Yield, and Size of Spears Produced Annually by Asparagus Plants Used as Pistillate Parents

Plant No.	No. Spears Produced Annually (3 Years)	Annual Yield 3 Years (Ounces)	Mean Size Spears Produced 3 Years (Ounces)
4–5	21.0	11.4	0.52
5–10	13.3	10.3	0.61
5–21	19.0	10.3	0.48

F not significant in any instance.

[1]Paper No. 1881 of the Scientific Journal Series of the Minnesota Agricultural Experiment Station.

TABLE II—THE NUMBER OF SPEARS, YIELD, AND SIZE OF SPEARS PRODUCED ANNUALLY BY ASPARAGUS PLANTS USED AS STAMINATE PARENTS

Plant No.	No. Spears Produced Annually (3 Years)	Annual Yield 3 Years (Ounces)	Mean Size Spears Produced 3 Years (Ounces)
2-12	21.7	18.9	0.95
3-9	20.3	15.3	0.78
3-16	26.0	19.2	0.72
4-17	27.3	16.0	0.58
5-2	32.7	17.1	0.56
5-32	3.7	2.0	0.46
Sig. Diff.	18.1	10.2	0.42
H. Sig. Diff.	28.4	16.0	0.66

presented in Table I and of the staminate parents in Table II. Analysis of variance suggest no differences between pistillate but significant differences between staminate parents.

Plant 5–32 was significantly inferior to plants 5–2, 4–17 and 3–16 in number of spears produced, and the difference between 5–32 and 2–12 approached significance. There were no significant differences between other plants in the number of spears produced. Likewise, plant 5–32 was significantly lower in yield than any other staminate parent. It will be noted that in only one case did a significant difference in mean size of spears appear between plants. That difference (0.49 ounce between plants 2–12 and 5–32) was only slightly above the minimum for odds of 19:1 and the analysis of variance showed an F value below the 5 per cent point in this instance.

TABLE III—ANALYSIS OF VARIANCE FOR MEAN DAYS FROM SEEDING TO EMERGENCE OF THE PROGENIES OF THREE PISTILLATE AND SIX STAMINATE ASPARAGUS PLANTS

Variation Due to:	D/F	Sum of Squares	Mean Square	S.E.	F
Series	1	76.56	76.56	—	—
Staminate	5	54.78	10.96	—	4.260*
Pistillate	2	7.46	3.73	—	1.450
Staminate×Pistillate	10	342.61	34.26	—	13.321**
Error	17	43.72	2.57	1.60	—
Total	35	325.14	—	—	—

*Exceeds 5 per cent point.
**Exceeds 1 per cent point.

TABLE IV—THE INTERACTION OF PISTILLATE AND STAMINATE PARENTS IN MEAN* DAYS TO SEEDLING EMERGENCE OF THEIR PROGENIES

Pistillate Parents	Staminate Parents						
	2-12	3-9	3-16	4-17	5-2	5-32	Mean
4-5	24.2	25.1	24.1	27.2	24.0	21.1	24.3
5-10	22.5	24.5	31.1	22.4	27.7	24.1	25.4
5-21	34.3	22.6	21.6	21.2	22.8	25.3	24.6
Mean**	27.0	24.1	25.6	23.6	24.8	23.5	24.8

*Sig. Diff. =3.38.
H. Sig. Diff. =4.64.
**Sig. Diff. between Staminates =1.95.
H. Sig. Diff. between Staminates =2.68.
Sig. Diff. between Diff. =4.78.
H. Sig. Diff. between Diff. =6.56.

TABLE V—ANALYSIS OF VARIANCE FOR WEIGHTS OF THE 2½ MONTH OLD PROGENIES FROM THE 18 COMBINATIONS OF THREE PISTILLATE AND SIX STAMINATE ASPARAGUS PLANTS

Variation Due to:	D/F	Sum of Squares	Mean Square	S.E.	F
Series	1	0.0016	0.0016	———	———
Staminate	5	0.0110	0.0022	———	1.571
Pistillate	2	0.0123	0.0061	———	4.357*
Staminate × Pistillate	10	0.0438	0.0044	———	3.144*
Error	17	0.0233	0.0014	0.0374	———
Total	35	0.0920	———	———	———

*Exceeds 5 per cent point.

COMPARISON OF THE PROGENIES

Data involving days from seeding to emergence are shown in Table III and indicate high significance for the interaction between staminate and pistillate parents. By calculating the standard error for the difference between means of crosses and multiplying by the t value (2) for 17 D./F. (2.110 and 2.898) a significant difference between means of crosses was calculated as 3.38 days, and a highly significant difference as 4.64 days. Similarly, by calculating the standard error for the difference between means of the progenies of the staminate parents and multiplying by the t values for 17 D./F., a significant difference between means of the progenies of the staminate plants was calculated as 1.95 days, and a highly significant difference as 2.68 days. The means of the various progenies are shown in Table IV.

It will be noted that the time was significantly longer in the case of crosses 5–21 x 2–12 and 5–10 x 3–16. Minor variations also appeared among the other crosses. The interaction effect is shown by considering the standard error for a difference between differences as calculated by the formula: $\sqrt{(\text{S. E.a})^2 + (\text{S. E.b})^2}$. When multiplied by the t value for 17 D./F., a significant difference between differences was calculated as 4.78 days, and a highly significant difference as 6.56 days. As an application of these figures, the progenies of crosses of 4–5 x 5–2 and 5–32 may be compared with those of crosses of 5–21 x 5–2 and 5–32. The difference between the former crosses was 2.9 days (not significant), and the latter was 2.5 days (not significant).

TABLE VI—THE MEAN WEIGHTS IN GRAMS OF 2½ MONTH OLD PROGENIES FROM THE 18 COMBINATIONS OF PARENT PLANTS

Pistillate Parents	Staminate Parents						
	2–12	3–9	3–16	4–17	5–2	5–32	Mean**
4–5	0.21	0.18	0.18	0.07	0.13	0.18	0.16
5–10	0.16	0.14	0.23	0.21	0.15	0.15	0.17
5–21	0.21	0.24	0.20	0.20	0.23	0.14	0.20
Mean	0.19	0.19	0.20	0.16	0.17	0.16	0.18

Sig. Diff. =0.08.
H. Sig. Diff. =0.11.
**Sig. Diff. between Pistillates =0.03.
H. Sig. Diff. between Pistillates =0.04.
Sig. Diff. between Diff. =0.12.
H. Sig. Diff. between Diff. =0.16.

These differences being opposite and therefore addible, total 5.4 days for the difference between differences. This is in excess of the requirement for significance, suggesting that an interaction existed between the parental combinations in question, so that 4–5 combined better with 5–2 and 5–21 better with 5–32.

Similarly, subtracting the time for the emergence of the progenies of cross 4–5 x 2–12 from the time of 4–5 x 5–32 gives a difference of 3.1 days (approaching significance) and favoring the cross involving the male parent 5–32 in early germination. Likewise, subtracting the time for the emergence of 5–21 x 2–12 from the time of 5–21 x 5–32 gives a difference of 9.0 days (significant) and also favoring the male parent 5–32. The difference between differences (5.9 days) was significant. Thus, the progenies of plant 5–32 were significantly earlier than those of 2–12 but were significantly greater in one cross than another. Therefore, if earlier germination were being considered as a desirable character to be developed in an improved strain, these data suggest the desirability of testing various parental combinations.

As indicated by Table V, the analysis of variance for growth rate of 2½ month old progenies shows the interaction of pistillate and staminate parents to be significant. This is considered to be a further suggestion that the parental combination should be the basis for selection. It appears that the parent plants react quite differently in different crosses. Table VI shows the means resulting from the different combinations.

By the procedure used for days to emergence, a significant difference between means was calculated as 0.08 grams, a highly significant difference as 0.11 grams. A significant difference between differences was calculated as 0.12 grams; a highly significant difference between differences as 0.16 grams. In one instance, there is a significant difference between a combination and the group mean, 4–5 x 4–17 having a mean of 0.07. It is of interest that both of these parents appeared favorably in other combinations. It is also significant that the progenies of 5–21 were heavier than those of 5–10 and 4–5. This may be a suggestion that in general 5–21 has value as a pistillate parent but it should be noted that it did not react favorably in all crosses particularly with the 5–32 staminate plant.

The apparent lack of vigor of the staminate parent plant 5–32 as indicated by its yield, number and average weight of spears produced, did not have a noticeable weakening effect upon its progenies. The progenies of 5–32 compared quite favorably with those of the other male parents, being the most rapid in emergence, and significantly so over the progenies of 2–12 and 3–16. In mean weight of 2½ month old plants, the progenies of 5–32 were lower than those of the other staminate parents but not significantly so. Further information is needed to determine definitely that the various progenies are different in vigor. However, the data available suggest that the field performance of male asparagus plants may not be a sound basis in selecting for increased vigor or rate of growth.

This is also true in general for the pistillate parents, although the evidence presented is not as complete as that on the staminate plants.

There was less variation between the pistillate plants. Plant 4–5, which showed a slight, but not statistically significant superiority over 5–10 and 5–21 in number and weight of spears produced over a three-year period apparently did not consistently transmit this vigor to its progenies as shown by the measurement used in this study. The progenies of 4–5 were significantly inferior to those of 5–21 in mean weight of 2½ month old plants. Certain differences occurred in the interaction between male and female parents, which may be an indication that the staminate and pistillate parents are of equal importance in transmitting vigorous growth to their offspring but that certain plants may prove to be good parents only when in combination with certain others, and that favorable combinations can best be determined by testing of progenies.

Correlation Between Parental Factors and Those of Their Offspring

Correlation coefficients were calculated to determine whether or not any relationship between the parental measurements considered and the early development of the offspring could be demonstrated. The mean yield, spear size, and number of spears of the parents were determined by averaging the data on the two parents involved in each cross. As an illustration, the mean yield of cross 4–5 x 3–16 was calculated by averaging the yield of the pistillate parent (11.4 ounces) with that of the staminate parent, (19.2 ounces), giving an average yield of 15.3 ounces. These averages were then correlated with the mean days to emergence and early weights of the corresponding progenies. There was no definite correlation in any case. This further illustrates that parental vigor was not transmitted. In later performance the progenies may not react the same as the young plants but any definite relationship was expected to appear in the young plants.

Summary

A total of three pistillate and six staminate asparagus plants and the progenies of their 18 possible combinations were tested for vigor. The pistillate parents did not differ significantly in yield, spear size, or number of spears produced. Staminate parent 5–32 was phenotypically weaker than other staminate plants used in the experiment. Progenies were compared as to days from seeding to emergence and weight at 2½ months of age. In regard to days to emergence, variation due to the interaction between staminate and pistillate plants was highly significant; the variation due to staminate plants was significant. Weights of 2½ months old progenies showed the variation due to interaction of staminate and pistillate plants to be significant, that due to pistillate plants to be significant. Of the phenotypic factors considered, none of the parental factors was significantly correlated with those of the progenies.

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Fertilizer and Storage Experiments with Squash

By J. R. HEPLER, *New Hampshire Agricultural Experiment Station, Durham, N. H.*

WINTER squash, *Cucurbita maxima*, is one of the more important vegetable crops grown extensively in New Hampshire. The crop is so bulky and the price so low per ton that comparatively small amounts are shipped into New England.

Fertilizer practices vary a great deal among different growers varying from the application of manure or commercial fertilizer or both in the hill, to these materials used broadcast or combinations of both methods.

For the 1939 trials a recently cleared southeastern exposure was chosen. In fact this crop of squash was the first crop grown on the land. The variety used was the Colby strain of Blue Hubbard. The whole area was covered with manure broadcast at the rate of 15 tons per acre. In addition to the manure the treatments mentioned in Table I were used. The squash was planted 8 feet by 8 feet and thinned to two plants per hill with a total of 36 hills per treatment. None of the plots had the required 72 plants because insects and mosaic disease killed a number of plants after thinning. The treatments were repeated once.

In this newly cleared land, nitrogen was apparently a limiting element, and the organic nitrogen in tankage gave the plant an early start and produced a higher yield.

To note the effect on growth of these various forms of fertilizer, one plant in each hill was measured once a week until the plants were around 12 feet in length. The last measurements on July 27 showed that fertilizer in the hill produced early growth. However, plants on plots where the fertilizer was broadcast caught up later in the season and yielded practically as much.

1940 RESULTS

In 1940, the squash was planted on a fertile plot that had been

TABLE I—GROWTH AND YIELD OF SQUASH IN 1939

Treatment	No. of Plants	No. of Squash Harvested	Yield Per Hill (Lbs)	Total Yield (Lbs)	Percentage Comparison	Average Growth July 27 (Inches)	Percentage Comparison Average Growth
Tankage 1 pound per hill+check treatment..........	47	78	44.0	1583.3	140.2	125.9	153.
750 pounds per acre of 5–8–7 broadcast+check treatment.	53	70	36.6	1319.3	116.8	63.2	77.
Check, manure at the rate of 15 tons per acre..............	51	58	31.4	1129.2	100.0	82.2	100.
5 pounds manure per hill+check treatment..........	56	67	36.5	1315.4	116.5	119.2	145.
5 pounds manure, 1 pound 5–8–7 fertilizer per hill+check treatment....................	49	72	43.9	1580.9	140.0	124.6	152.
1 pound 5–8–7 fertilizer per hill+check treatment........	63	80	38.5	1385.9	122.7	99.1	121.

TABLE II—YIELD OF SQUASH HARVESTED IN 1940

Treatment	No. Plants	No. Squash Harvested	Weight (Lbs)	Comparison (Per Cent)	Yield Per Plant (Lbs)	Yield Per Hill (Lbs)
1 pound per hill tankage + check treatment	66	71	1455.0	95.1	22.0	41.6
750 pounds per acre of 5-8-7 broadcast + check treatment	85	86	1587.1	103.7	18.7	45.3
Check, 15 tons of manure per acre	79	84	1530.2	100.0	19.4	43.7
5 pounds manure per hill + check treatment	79	84	1623.8	106.1	20.6	46.4
5 pounds manure, 1 pound 5-8-7 per hill + check treatment	80	83	1584.2	103.5	19.8	45.3
1 pound 5-8-7 per hill + check treatment	98	98	1660.8	108.5	16.9	47.5

planted to garden crops for 20 years. The fertilizer treatment was similar to 1939 with a check treatment of 15 tons of manure per acre broadcast over the whole field.

No measurements of young plants were made since it was felt that handling the plants during the measuring process tended to spread disease. Plants affected with mosaic disease were removed as fast as the disease appeared. The above results seem to show that in fertile, well tilled soil any normal fertilizer treatment will suffice provided insects and diseases are held in check.

EFFECT OF VARIOUS INSECTICIDES ON SQUASH YIELD IN 1939

To control the various squash insects, the plants were dusted crossways of the fertilizer treatments with four different dusts, about six applications being made a week apart.

TABLE III—EFFECT OF VARIOUS DUSTS (1939)

Treatment	No. Plants on 54 Hills	No. of Squash	Total Yield (Lbs)	Comparison (Per Cent)	Growth August 3 (Inches)	Comparison (Per Cent)
Niagara Cucurbit Dust	82	116	2172.9	110.0	148.2	96.
Calcium Arsenate Lime Dust 10-90	71	95	1971.6	100.0	154.7	100.
Pyrocide	79	103	2030.8	103.0	134.8	87.
Niagara Mixture 789	85	111	2138.7	108.5	144.7	94.

The calcium arsenate dust, home mixed was taken as a check because it is readily available. The common belief that lime checks the growth of cucurbit vines is not borne out by the measurements, although this material did not keep as many plants alive as the other ones did. The squash bug was not controlled by any of the treatments.

The 1940 dusting results are given in Table IV.

Again none of these treatments controlled squash bugs. The yields again were closely correlated with the number of surviving plants.

TABLE IV—EFFECT OF VARIOUS DUSTS (1940)

Treatment	No. of Plants	No. of Squash	Yield (Lbs)	Per Cent Comparison
10-21 Niagara Dust	84	85	1537.7	108.2
Rotenone	72	77	1430.4	100.7
Red Cupric Oxide Cucurbit Dust	76	79	1447.0	101.8
Calcium Arsenate Lime—10-90 Dust	70	73	1420.8	100.0
10-20 Niagara Dust	72	75	1444.3	101.7

Storing Experiment

During harvesting, the squashes were handled very carefully although the stems of a number were broken off to see whether this is an important cause of storage rot. No weight measurements were taken but there was no observable difference in their keeping qualities.

The effect of waxing well-matured squash and also dipping them in copper sulphate and formalin solution at the rate of 1 to 200 were studied. Twenty carefully selected squashes were used in each treatment, half of which were injured by cutting off the blossom end before treatment. They were stored in a 45 degrees F temperature. The results of these treatments are shown in Table V.

TABLE V—Effect of Different Treatments on Storage of Squash

Treatment	Weight of 10 Squash Nov 16 (Lbs)	Percentage of Original Weight Dec 13	Per Cent Original Weight Jan 10	Per Cent of Original Weight Feb 15
Waxed and injured	185	95.5	95.5	92.4
Waxed and uninjured	185	95.0	95.7	93.2
Injured	181¾	92.8	93.7	89.5
Uninjured	219¾	93.5	94.5	90.3
Injured dipped in $CuSO_4$, 1–200	203½	94.7	94.8	89.9
Uninjured dipped in $CuSO_4$, 1–200	170¾	94.3	93.6	89.6
Injured dipped in formalin, 1–200	196½	96.1	95.3	93.1
Uninjured dipped in formalin, 1–200	223	95.3	95.4	92.9

Average per cent of original weight Feb 15 injured—91.2
Average per cent of original weight Feb 15 uninjured—91.5

Plant Tests as a Guide to Fertilizer Treatment of Tomatoes (Preliminary Report)

By E. M. EMMERT, *University of Kentucky, Lexington, Ky.*

THE data, analysis of results and detailed discussion of this paper will be published in a Kentucky Bulletin. The results are presented of 5 years' work in the Station greenhouse on soil plots, of 6 years' work in field plots at the Lexington station, of 2 years' work on the poor soils of the substation at Princeton, Kentucky, and of two crops grown by the soilless culture method in the greenhouse. Numerous plant tests (1) were made on all these crops and the results correlated with yield. Drouth caused moisture to be a primary factor in some cases where irrigation could not be done, and these results are not comparable with those from crops which received ample moisture. However, despite moisture influences, definite results have been obtained from year to year and recently have shown high significance statistically, even up to the rigid level of $P = .01$ which is considered as showing the relationships to be significant without any doubt.

One conclusion that has been reached in all trials is that the plant tests show response to nutrient treatment, whether in the soilless cultures, greenhouse soil plots or in the field, and since the results of the tests are highly correlated with yield and growth response they must show quite accurately the availability of nutrients to the plant. In fact, plant tests seem to be a better measure of the nitrogen and phosphorus the plant is able to absorb than are soil tests.

The general conclusions to be gathered from all the data are that the soluble nitrogen and phosphorus should be rather high (1,500 to 2,000 parts per million of nitrogen, 100 to 150 parts per million of phosphorus, in the lower green mature petioles) in the early period of growth before any fruits set; the nitrogen should then drop to around 1,000 parts per million just prior to fruit setting time, with phosphorus increasing to 200 or more parts per million. Then, after the first three or four clusters of fruit on plants pruned to one stem (may be several clusters on each branch of unpruned plants) are set and the fruits are starting to grow, the nitrogen should be increased to 2,000 to 2,500 parts per million, with the phosphorus maintained above 200 parts per million until the fruits have sized up and the lower clusters are ripening. After ripening has progressed somewhat the nitrogen should be reduced to around 1,000 parts per million to stop late vegetative tendencies at the expense of late yield. Maintenance of high phosphorus at this stage seems unimportant.

Plant tests are the best method to follow the course of nutrients during the season and a grower will benefit greatly from making these tests which are comparable to rapid soil tests in ease of procedure and rapidity. However, even if plant tests are not made, a grower may well make effort to apply nitrogen and phosphorus in such a way that the course of nutrients will follow the above changes in amounts throughout the growth of the plant.

In practice, the grower should apply amounts of a quick-acting ferti-

lizer such as sodium nitrate so that the plants will make a rapid and vigorous early growth, to develop a large-framed plant. The amount to apply, of course, will depend on the natural soil fertility (usually 50 to 250 per acre). If it is certain that nitrogen and phosphorus are needed, some may be applied at plant setting time. If it is not certain, plant tests will readily determine this about one week after setting. Care must be exercised with nitrogen, however, not to apply so much that it will be excessive as fruit setting approaches. Slowly available fertilizer should not be applied unless it is certain it will not become rapidly available just before fruit set and cause excesses of soluble nitrogen at this critical period of high demand for phosphorus. At this time if nitrogen is excessive in comparison to the phosphorus and carbohydrate supply, most of the blossoms will drop or fail to develop and early fruiting will be greatly reduced. For this reason care should be taken to not add fertilizers which will greatly increase nitrogen just before fruit setting time, which often happens when large amounts of slowly available fertilizer are added, especially on a soil already rather high in organic nitrogen.

Just before fruit setting, a 1,000-pound per acre application of 20 per cent superphosphate (smaller amounts of higher analysis phosphate may be even better), applied in a 2-inch deep furrow as close to the plants as possible, will work wonders in fruit set, even on some highly phosphatic soil. This depends on the fixing nature of the soil. Undoubtedly, it is best to apply at least part of the phosphorus just prior to fruit setting, in a soil of high phosphorus-fixing tendency. (Most heavy soils are of this type. Plant tests will help to show if this is the case.)

Then, after fruits set, a heavier side dressing of nitrogen may be used (100 to 300 pounds of sodium nitrate) but it is best to avoid an excess so that the absorption of nitrogen will decrease with the maturity of the crop.

This care in the reducing of nitrogen and increasing of phosphorus just before fruit set is of special importance to the early market gardener and greenhouse producer and he can afford to make special effort towards this end since the set and development of fruit on the first clusters are all important to him.

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Soil Acidity for Watermelons on Sand

By JOHN D. HARTMAN and F. C. GAYLORD, *Purdue University, Lafayette, Ind.*

IN a previous publication the authors (1) presented results of soil acidity experiments with muskmelons and sweetpotatoes on Princeton and Elk fine sands. The data reported in this paper were obtained in 1940 on the plots described in the previous publication and are presented as information on growth of watermelons relative to the pH of the soil. Treatment 1 consisted of an application of 1,000 pounds of elemental sulfur per acre on September 24, 1937. The plots of treatment 2 received 333 pounds of sulfur per acre at the same date. No soil amendments were added on the plots of treatment 3. For treatment 4, 1,000 pounds of ground limestone were applied in September, 1937 and sulfuric acid equivalent to 433 pounds of sulfur, on May 12, 1939. The application to plots of treatment 5 was 3,000 pounds of limestone, put on in 1937. Ground limestone, at the rate of 9,000 pounds per acre, was used on the plots of treatment 6 on September 24, 1937; hydrated lime furnishing as much calcium as 2 tons of limestone per acre was added May 12, 1939. No further materials for modifying the acidity have been added.

During the winter and early spring of 1939–1940 the plots were in rye, which grew luxuriantly. This rye was top-dressed with 100 pounds of sulfate of ammonia and 50 pounds of 50 per cent muriate of potash per acre on March 19 and again on April 6, 1940. It was disked and plowed under April 26, when it was about 2 feet tall.

Seeds of the variety Hawkesbury, which is highly resistant to Fusarium wilt, were sown April 10 in veneer bands in a cold-frame. The plants were set in the field on May 23, being spaced 14 by 7 feet. At that time they had several fully expanded true leaves. On May 30 fertilizer was applied at the rate of 100 pounds of sulfate of ammonia, 900 pounds of 20 per cent superphosphate, 300 pounds of 50 per cent muriate of potash and 15 pounds of borax per acre. These ingredients were mixed together and scattered along the bottoms of the deep furrows in which the plants had been set and, to a much lesser extent, on the surface of the ground around the plants. There were no further applications of fertilizer.

Rainfall during April exceeded 8 inches, but there were no heavy rains from the time the plants were set until after the date of last harvest, October 2. On only three days during this whole period did rainfall exceed a half inch: May 25, 0.54 inch; July 11, 0.69 inch; and September 24, 0.68 inch. Nevertheless, in spite of drought, detrimental to nearly all other crops, the watermelons made excellent growth.

Half of each plot was sprayed with an insoluble copper spray on July 13, August 1, and August 20. Presumably on account of the drought these sprays had no apparent effect on the plants or on yields. Foliage was still in excellent condition even after harvesting was discontinued.

Soil samples were taken on each plot three times during the season.

At each time eight borings to a depth of 8 inches were made on each plot or each half plot. A quinhydrone electrode method was used for measuring pH.

Refractive indices on the juice of melons from all treatments were obtained with Zeiss hand refractometers. For this testing, two ripe melons from each plot of the first and third replicates and one from each plot of the other four replicates were used. The melons for this purpose were chosen and marked early in the season. All ripened within the period from August 10 to August 30. In each case the juice sample was taken from the seed region. Duplicate readings were made. The refractometers were kept at temperatures at which they had been recently checked with solutions of known refractive index. They are calibrated to read directly in percentages of sucrose, though, of course other soluble materials affect the readings.

Other characteristics of these sample melons, including taste and color, were also recorded.

Results and Discussion

The principal data are summarized in Table I. Yields of No. 1 melons only are given because practically all defective and stunted fruits were removed before maturity.

As is usual, pH values were higher in the spring than in the summer. Comparisons made between data of August 1940, and those of August 1939, show a tendency toward increased acidity, especially in the case of treatment 3, to which no materials have been added specifically for the purpose of changing the acidity. These differences are probably worthy of notice, because both 1939 and 1940 were drought years on this sand and in both nitrates should have had time to accumulate in abundance prior to the date of sampling. The trend is almost undoubtedly due to a continued use of sulfate of ammonia as a source of nitrogen. The plots of treatment 3 have been most affected, presumably because of the smaller quantity of buffering chemicals in the soil there.

From the table it may be seen that soil acidity, within the range of

TABLE I—Effect of Soil Acidity on Yields and Soluble Solids Content of Watermelons

Treatment Number	Soil Acidity				Yield of No. 1 Melons		Soluble Solids in Fruit, Expressed as Sucrose (Per Cent)
	August 29, 1939 (pH)	May 22, 1940 (pH)	July 17, 1940 (pH)	August 12, 1940 (pH)	Total Weight (Pounds Per Acre)	Weight Per Fruit (Pounds)	
1	4.6	5.1	4.8	4.7	25,312	25.1	9.6
2	5.4	5.4	4.9	4.9	25,748	25.3	9.8
3	5.8	5.7	5.3	5.2	26,263	24.4	9.6
4	5.2	5.7	5.3	5.2	25,970	24.9	9.7
5	6.7	6.6	6.3	6.3	27,701	24.9	9.7
6	7.6	7.6	7.3	7.4	27,390	24.3	10.0
Difference necessary for significance (19:1)	0.4	0.3	0.4	0.3	N.S.*	N.S.	N.S.

*Not significant.

pH 4.7 to 7.4, for August readings, had no significant effect on yield, size or soluble solids. Averages for taste index numbers were also all practically the same. It is possible that failure of differences to appear was partly attributable to the dry weather. This postulate does not, however, appear well grounded, because sweetpotatoes in the dry year of 1939 did show large differences; furthermore, the plots are regularly plowed to a depth of 10 to 12 inches and so all the surface soil should have the same average acidity as did the soil samples.

There are few other data in the literature with which these results may be compared. Hartwell and Damon (2) in 1914 rated watermelons as a crop somewhat adversely affected by the liming of a very acid soil on which most other crops grew poorly without liming. Their data, however, do not consistently support this conclusion and may be considered to show, on the whole, no significant effect of liming. Jones and Rosa (3) state that in California watermelons are successfully grown on slightly alkaline soils.

Where the natural manganese supplying ability of a soil is low, a detrimental effect is of course likely when the pH is brought above 6.5 or 7.0. The soils of this experiment are, however, rather high in available manganese, as indicated by tests based on the rapid methods of Spurway (4).

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The Phosphorus Level of a Chenango Fine Sandy Loam Required by Four Vegetable Crops

By JOHN BUSHNELL, *Ohio Agricultural Experiment Station, Wooster, Ohio*

DURING the course of a fertilizer experiment with four vegetable crops on Chenango fine sandy loam near Marietta, in southern Ohio, plots receiving annually 400 pounds of 16 per cent superphosphate became saturated to the point where residual phosphorus was amply available to all of the crops. This was clearly evident when the phosphate was omitted from the fertilizer of one plot beginning in 1931. For the following four years the yields of all the crops, tomatoes, cucumbers, cabbage, and sweet corn, were as high on this plot as on an adjacent continuously phosphated plot (2). However, in the fifth and sixth years the tomatoes and cucumbers began to show some indications of phosphorus deficiency, but the cabbage and sweet corn continued to give as high yields as on the phosphated plot.

Soil samples collected in the spring of 1931, when the phosphate was first omitted, tested 180 pounds of "readily available" phosphorus by Truog's method (6), and 100 pounds per 2,000,000 were readily extracted with water. The procedure for determining the water-soluble phosphorus was the same as Truog's method, except that water was used instead of a weak acid solution, and several refilterings were necessary to get a clear filtrate. This soil testing 180 pounds of available phosphorus by Truog's method, and 100 pounds water-soluble, contained sufficient available phosphorus to maintain the yield of tomatoes and cucumbers for at least four years.

After the yields of tomatoes and cucumbers began to decline, soil samples were again collected in the fall of 1938. The available phosphorus at this time was 120 pounds by Truog's test of which 50 pounds were water-soluble. This proved to be sufficient for cabbage and sweet corn for at least two more years.

Sweet corn has produced good crops on soil with even less available phosphorus. During the first 16 years of the experiment sweet corn thrived without any phosphate fertilizer whatever, whereas the other crops responded to phosphate applications from the outset. At the end of 16 years, some of the plots without phosphate fertilizer tested about 90 pounds of phosphorus by Truog's test of which 20 pounds were water-soluble.

Thus the four crops fall into three distinct classes. Tomatoes and cucumbers require a high level of available phosphorus, cabbage a somewhat lower level, and sweet corn a distinctly lower level.

AVAILABILITY OF THE PHOSPHORUS FROM MANURE

The above data may not be strictly valid for cucumbers, because cucumbers have not given as good yields on any of the fertilized plots as on manured plots. Tests of the soil from a plot receiving 8 tons of manure per acre showed 230 pounds of available phosphorus by Truog's method and 70 pounds water-soluble. As manure has been

TABLE I—Tests for Phosphorus on Soil Containing Ample Available Phosphorus for the Crops Listed

Plot	Year Sampled	Annual Phosphate Application Per Acre of Preceding Years	Available Phosphorus		Proved Sufficient For
			Water Extract	Truog's Method	
31	1931	400 pounds 16 per cent superphosphate	100	180	Tomatoes
25	1938	8 tons manure	70	230	Cucumbers
31	1938	None since 1930	50	120	Cabbage
32	1931	None since 1914	20	90	Sweet corn

applied annually to this plot it cannot be stated that the *residual* phosphorus was ample for cucumbers, as stated above for the other crops, but rather that at this phosphorus level 8 tons of manure per acre supplied sufficient phosphorus for cucumbers. The data of this plot are included in the summary, Table I.

Discussion

It is well known that most soils in western irrigated districts do not respond to phosphate fertilizer, but in eastern states only rarely do fertilizer experiments indicate that a soil has been phosphated to the point where maximum crops can be grown without phosphate in the fertilizer. Aside from the results in Ohio, three other instances have come to the attention of the writer. Odland and Crandall (5), in Rhode Island, obtained an 8-year average yield of 482 barrels of cabbage per acre from an 8–0–8 and 474 barrels from an 8–8–8. Brown (1) mentioned an experiment on an old tobacco soil in Connecticut in which potatoes did not respond to phosphate in the fertilizer. Hester (3) estimated the phosphorus fixing capacity of Norfolk sandy loam at about 5,000 pounds of phosphoric acid per 2,000,000 pounds of soil and found one grower's field with over 6,000 pounds.

Thus, here and there, in the vegetable districts of the eastern states are fields which have been phosphated to the point where residual phosphorus is amply available to crops. In view of the almost universal practice of applying much larger quantities of phosphorus in the fertilizer than removed by the crops, the number of fields phosphated to this degree must be increasing. Presumably, relatively small amounts of phosphate fertilizer would be required to maintain yields on such soils. By suitable soil tests, together with a knowledge of the requirements of various crops, it would seem feasible to detect such soils and to modify the fertilizer recommendations accordingly.

This brings up the question of the accuracy of soil tests. The various procedures now being used have not been comprehensively compared on the soils of this experiment, but Morgan's (4) test for phosphorus, which is the one most commonly used in Ohio, has not proved sensitive enough to be of much value. Soils ranging from 50 to 150 pounds of water-extractable phosphorus could not be differentiated by Morgan's procedure, when the extracting solution was poured through the soil sample. On the other hand, Truog's (6) procedure of extracting by shaking for 30 minutes has given good agreement with the crop

response, good agreement with the known quantities of phosphate previously applied, and indicated two to three times as much available phosphorus as shown by the water extractions.

The tentative recommendation for growers in the Marietta district is to have their soils tested by Truog's method, compare the findings with the data of Table I, and, if the available phosphorus is near or above the crop's requirement, to reduce the phosphoric acid content of the fertilizer to 20 to 40 pounds per acre.

Aside from this practical deduction, the facts of special scientific interest in this experiment may be summarized as follows: (a) With only moderate applications of superphosphate for a period of 16 years, the accumulation of available phosphorus reached the point where it was ample for tomatoes. (b) The crops grown here differ in the phosphorus level required and, consequently, the crops must differ physiologically in their capacity to obtain phosphorus from the soil.

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Growth and Yield of the Tomato Plant When Hardened with Certain Nutrient Solutions[1]

By E. P. Brasher, *West Virginia University, Morgantown, W. Va.*

THE hardening of tomato plants before planting in the field has long been considered necessary by many research men and commercial growers. In recent years, however, a few publications have shown detrimental effects from this practice. In 1937 Brasher and Westover (1) found that in West Virginia the hardening of young tomato plants, even to a moderate degree, induced a stunting effect, made them no more able to survive unfavorable early spring conditions, and resulted furthermore in lower yields. These findings were supported by Porter's (2, 3) field trials in Connecticut and by the work of Crist (4) under greenhouse conditions in Michigan.

Because of the increased popular interest in hydroponics and of the possibility that plant growing in soilless cultures may become commercially important, the present investigation was undertaken to determine whether tomato plants could be hardened with certain nutrient solutions. Another aim was to determine whether plants hardened in this manner responded similarly to those hardened in the ordinary manner as reported by previous investigators.

Plant Growing and Procedure of Hardening

Tomato seeds of the Break O'Day variety were sown in flats on March 13 and on April 2 the seedlings were transplanted into clay plots containing washed sand. The plants were grown with a nutrient solution suggested by Withrow and Biebel (5) in the greenhouse at Morgantown.

Ten days before the plants were set in the field, three series of 50 plants were selected for comparison. In series 1 the concentration of the nutrient solution was increased with potassium sulphate from one to about eight atmospheres. The original nutrient solution for series 2 was increased to approximately eight atmospheres using all of the major fertilizer salts. Series 3 was grown with the original solution, except that the nitrogen was decreased to a point of deficiency. If any treatment that checks or slows up plant growth has a hardening effect, the plants in series 1 and 3 were hardened, while those of series 2 remained in a tender condition.

At the end of 10 days there was a very pronounced difference in the appearance between the plants of the 3 series. The plants of series 1 were fairly stocky, medium light green in color, and had increased slightly in height. The plants of series 2 had made vigorous growth, were medium dark green in color, and were much taller than the plants of the other two series. They also exhibited some flower buds and appeared to be very vegetative. The plants of series 3 were small and somewhat spindly and apparently had not increased much

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in size. The foliage was very light green in color, with the lower leaves decidedly yellowish.

The plants of the first and third series did not show many of the visual characteristics of hardiness but apparently, to a certain extent, each was hardened. This was shown by placing representative plants of all series under conditions which were conducive to wilting. After four hours of this treatment the plants from the first series were apparently unaffected, those from the second were severely wilted, and those from the last were only slightly wilted. Judging from this test the plants of series 1 and 3 were moderately hardened, while those in series 2 remained in a succulent condition.

Field Technique and Observations

The field trials were located at Morgantown on a Tilsit silt loam. The planting consisted of six rows, each row of 21 plants spaced 5 feet apart with the plants 5 feet apart in the row. The plants of the three treatments appeared in the same sequence in the rows, which resulted in a systematic distribution. A starter solution of 4.25 pounds of a 5–10–10 fertilizer mixture in 50 gallons of water was used at the rate of 1 pint per plant at setting time. The plants were set on May 22 and shortly afterwards an application of 1,200 pounds per acre of a 5–10–5 fertilizer mixture was applied in bands around the plants. Individual plant records consisted of the number and the weight of fruit of the marketable and total yields. All tomatoes were considered marketable that weighed three or more ounces and were of desirable market quality.

Seventeen days after setting, there were wide visible differences between the hardened and the tender plants. Regardless of treatment, all the plants were darker in color, but apparently the rate of growth was much faster in the tender plants. The hardened plants (series 1 and 3) had a few flowers, they had increased slightly in size, and no lateral shoots had developed. The tender plants possessed many flowers, they had increased rapidly in size, and new axillary shoots were growing. Superior differences favoring the tender plants were still evident at the first harvest period.

In the analysis of the yield data, the mean values of the measurements were obtained from the individual plants of the various treatments. The difference between these mean values was determined. A difference between means greater than 3.2 times its probable error has been regarded as significant.

Presentation and Discussion of Data

From early season observations it was apparent that the hardening treatments had caused a delay in growth of the tomato plants after transplanting and that they had also reduced the production of early fruit. Yield evidence supporting these observations was shown by the rapidity with which the plants came into production. At the first harvest on July 23, 52 per cent of the tender plants yielded marketable fruit as contrasted with 26 per cent of the plants in each of the hardened series.

In Table I a comparison of the mean individual plant yields shows

TABLE I—COMPARISON OF MEAN YIELDS FROM TENDER PLANTS AND PLANTS HARDENED WITH CERTAIN NUTRIENT SOLUTIONS

Grade of Fruit	Determination	Treatment*	Yield	Difference	D/P. E.
Early Yields (July 23 to August 12, 1940 Inclusive)					
Marketable	Number of fruits	1 2	4.09 ±0.16 4.98 ±0.13	0.89 ±0.21	4.24
		1 3	4.09 ±0.16 3.98 ±0.15	0.11 ±0.22	0.50
		2 3	4.98 ±0.13 3.98 ±0.15	1.00 ±0.20	5.00
	Yield (Pounds)	1 2	1.73 ±0.08 1.99 ±0.05	0.26 ±0.09	2.89
		1 3	1.73 ±0.08 1.57 ±0.07	0.16 ±0.11	1.45
		2 3	1.99 ±0.05 1.57 ±0.07	0.42 ±0.09	4.67
Total	Number of fruits	1 2	4.34 ±0.17 5.46 ±0.15	1.12 ±0.23	4.87
		1 3	4.34 ±0.17 4.96 ±0.21	0.62 ±0.27	2.30
		2 3	5.46 ±0.15 4.96 ±0.21	0.50 ±0.26	1.92
	Yield (Pounds)	1 2	1.77 ±0.08 2.08 ±0.05	0.31 ±0.09	3.44
		1 3	1.77 ±0.08 1.78 ±0.07	0.01 ±0.11	0.09
		2 3	2.08 ±0.05 1.78 ±0.07	0.30 ±0.09	3.33
Yields for Entire Season, 1940					
Marketable	Number of fruits	1 2	22.61 ±0.74 26.80 ±0.85	4.19 ±1.13	3.71
		1 3	22.61 ±0.74 22.13 ±0.90	0.16 ±1.17	0.14
		2 3	26.80 ±0.85 22.13 ±0.90	4.67 ±1.24	3.77
	Yield (Pounds)	1 2	7.90 ±0.28 9.16 ±0.30	1.26 ±0.41	3.07
		1 3	7.90 ±0.28 7.69 ±0.32	0.04 ±0.43	0.09
		2 3	9.16 ±0.30 7.69 ±0.32	1.47 ±0.44	3.34
Total	Number of fruits	1 2	32.60 ±1.04 38.56 ±1.21	5.96 ±1.59	3.75
		1 3	32.60 ±1.04 33.28 ±1.35	0.31 ±1.70	0.18
		2 3	38.56 ±1.21 33.28 ±1.35	5.28 ±1.81	2.91
	Yield (Pounds)	1 2	9.64 ±0.33 11.28 ±0.33	1.64 ±0.34	4.82
		1 3	9.64 ±0.33 9.81 ±0.40	0.07 ±0.52	0.13
		2 3	11.28 ±0.33 9.81 ±0.40	1.47 ±0.52	2.83

*Treatment 1 Plants hardened with a strong potassium solution.
2 Tender plants.
3 Plants hardened with a solution that was deficient in nitrogen.

that the tender plants were significantly superior to the hardened plants in nearly all of the yield measurements. This superiority in acre yield probably would have been greater, had the plants been spaced at the usual commercial planting distance. No significant differences were found in a comparison of the plant measurements between the two series hardened by the different methods.

A striking difference between the tender and hardened plants is shown when the mean yield differences are expressed in percentages. The plants of series 1, which were the more productive of the two series of hardened plants, yielded 12 per cent less early and 15 per cent less total marketable fruit than did the tender plants. These data, together with those reported by other workers, tend to support the belief that any method used which results in stunting or hardening young tomato plants permanently slows up their field performance, probably decreasing the yield roughly in proportion to the severity of the hardening treatment.

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The Response of Four Vegetable Crops to Different Nitrogen Carriers[1]

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THE nitrogen in commercial fertilizers may be obtained in a number of carriers including both organic and inorganic forms. The question is often raised as to the relative efficiency of nitrogen obtained from these various carriers, and more particularly in recent years, since a number of new sources have come into general use. Comparisons of a number of carriers have been made at the Rhode Island Agricultural Experiment Station over a period of many years. Two earlier publications (1, 2) have presented data relating to the relative efficiency of nitrate of soda and sulfate of ammonia on limed and unlimed soils. When the same soil reaction was maintained by heavier liming on the sulfate of ammonia plats than on those receiving the nitrate of soda, the two sources were generally about equally effective as sources of nitrogen. This paper reports briefly some of the heretofore unpublished data obtained in studies conducted in 1932 with Early Wonder table beets and New York lettuce, also later studies begun in 1933 and continued through 1939 in which Bloomsdale Savoy spinach and Golden Acre cabbage were included.

The experiments were conducted on the market garden field plats, which have been in continuous vegetable culture since 1916. The plats selected had received uniform treatment, including applications of stable manure, for a number of years previous to the present trials. Prior to 1932, and during the course of the investigations, necessary lime additions were made each year as required to maintain the soil acidity level between pH 6 and pH 7. The soil is a fine sandy loam of medium to high fertility and, in general, has indicated a marked response to medium amounts of nitrogen with most crops.

Seven nitrogen sources were used as individual nitrogen carriers. Each of the single nitrogen sources comprised a component part of a complete fertilizer mixture approximating a 5–10–5 analysis. In the initial experiment, each plat received applications equivalent to 1,200 pounds per acre. In the later studies, fertilizers were applied at the rate of 1,500 and 1,800 pounds per acre annually to spinach and cabbage, respectively. All fertilizer applications were broadcast at the time of planting.

With the exception of experiments conducted with ammophos, phosphoric acid was obtained from superphosphate, while potash was obtained from muriate of potash. The small part of the nitrogen content used to augment the nitrogen of the ammophos carrier was supplied by nitrate of soda. When used in combination, nitrate of soda and sulfate of ammonia comprised a mixture of approximately one-third nitrate of soda and two-thirds sulfate of ammonia. All plats were replicated and treatments randomized to allow a statistical interpretation.

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[1]Contribution No. 583 of the Rhode Island Agricultural Experiment Station.

Results

Table I combines the yields for six years, showing the total of each plat in 1932, and the average yield per acre for each plat during 1933 to 1937, inclusive. In 1932, both lettuce and beets were grown as early crops. From 1933 to 1937, inclusive, spinach was grown as an early crop, followed on the respective plats by late cabbage.

Table I indicates that yields of beets and lettuce were not significantly influenced by any of the single nitrogen sources employed. However, when yield comparisons are made, it is evident that minor differences were brought about by the different nitrogen carriers. The apparent lag in yields of both crops on the plats receiving sulfate of ammonia, and the indicated smaller yield of beets obtained on the nitrate of soda plats, do not substantiate previous conclusions as to the relative effectiveness of these materials. It seems quite probable that these differences occurred as normal yield variations under the prevailing conditions. Such an explanation seems plausible in view of the fact that only one year's data are involved, and consequently only a few observations were made.

On the average, there was little difference in the comparative effectiveness of the various nitrogen carriers for the early spinach or cabbage. As might be expected, considerable variation occurred among plats during the separate years of the experiments. However, the data, when represented as a 5-year average, indicate very conclusively the general crop response obtained. Considering the results obtained over the 5-year period, the data in Table I indicate that plats receiving nitrate of soda, sulfate of ammonia and the combination of these two sources were about equally effective for spinach. The data show these yields to be significantly larger than yields obtained on all other plats. There were no significant differences in total yield of spinach on the remaining plats.

The data, given in Table I, show that plats fertilized with nitrate of soda produced the highest yields of cabbage, but the average yield of 376 barrels per acre was not significantly greater than the average

TABLE I—Effect of Nitrogen Carriers on Yields per Acre of Beets and Lettuce (1932) and on Average Yields of Spinach and Cabbage (1933 to 1937)

Nitrogen Carrier	1932		Five-Year Average 1933–1937	
	Lettuce (Boxes)	Beets (Dozen Bunches)	Spinach (Bushels)	Cabbage (Barrels)
Sulfate of Ammonia	1801	1722	1320	339
Nitrate of Soda (Arcadian)	1961	1697	1335	376
Calnitro	1903	1820	1237	351
Urea	1938	1807	1206	312
Ammophos	1824	1698	1216	321
Calcium Nitrate	—	—	1242	368
Nitrate of Soda—Sulfate of Ammonia	—	—	1299	348
Difference required for significance	Not significant*	Not significant*	54†	37†

*Not significant with respect to residual error.
†Calculated F value exceeds 1 per cent level.

TABLE II—Average Yield per Acre of Spinach and Cabbage With Two Different Sources of Nitrate of Soda (1936–1939)

Nitrogen Source	Spinach (Bushels)	Cabbage (Barrels)
Chilean Nitrate of Soda	1281	345
Arcadian Nitrate of Soda	1317	331

yield obtained on the calcium nitrate, calnitro, nitrate of soda-sulfate of ammonia or the sulfate of ammonia plats. Although the average yields obtained on the plats receiving ammophos and urea were significantly lower, the apparent decrease does not appear to be great enough to suggest that these materials are less effective as sources of nitrogen.

In response to several inquiries, further experiments were begun in 1936 and continued for four years in which synthetic and Chilean nitrate of soda were compared. Spinach and cabbage were grown and the fertilizer applied at the same rate per acre as in previous trials. The average yields for 1936 to 1939, inclusive, are presented in Table II.

The data in Table II show that under the conditions of the test, neither source of nitrate of soda used was more effective than the other for the two crops. There was a small difference in average yield in favor of Arcadian nitrate of soda for the early spinach and an opposite effect for the late cabbage crop.

Discussion and Conclusions

Many experiments have been made in different sections of the country on the relative efficiency of various sources of nitrogen for commercial fertilizers. In some cases certain carriers have been the most efficient while in others there has been very little difference between the effectiveness of the various sources. The chief factors which seem to determine the relative efficiency of the various sources are soil type, soil reaction, kind of crop grown, climate, residual fertility of the soil and method of use. Any or all of these factors may have an important bearing on the results obtained. The conditions under which the test reported here was made were such that relatively small differences in efficiency might be expected between the various sources used. The soil was of a medium texture, it was well limed, minor elements were probably present in sufficient quantity, and extreme weather conditions were not encountered. Using the various materials in a fertilizer mixture rather than as side dressings also tended to eliminate differences. Calcium cyanamid used in this way for several years was not a satisfactory source and was discontinued. It will be noted that no natural organic source of nitrogen was included since many experiments at this station have shown that under conditions such as these, the much less expensive inorganic sources can be used more economically for the greater portion of the nitrogen requirements. Wessels and White-Stevens (3) have recently reported similar findings for spinach under Long Island conditions. It should be stated, however, that some natural organics are usually used in the fertilizer mixture as conditioners and to lengthen the period over which nitrogen

will be available. The amounts of such organics that it will be necessary to use will depend on the local conditions.

Although there were considerable variations from year to year in the response of the four crops used in these experiments to different nitrogen carriers it seems logical to conclude that all were satisfactory sources and that relative cost, specific crop or use and convenience of obtaining a supply should be the governing factors in making a selection. In considering the cost it should be kept in mind that acid reacting sources such as sulfate of ammonia will require more frequent liming of the soil than will materials such as nitrate of soda.

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Fertilizers for New Jersey Sweet Potatoes

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Abstract

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IT PRESENTS yield data where fertilizer in dry and liquid form were compared. Also data are presented from a comparison of different starter solutions. A 13–26–13 starter solution produced the highest yields. A comparison between different applications of dry fertilizer indicated that the best yields could be obtained where the fertilizer was placed under the plowed soil under the row.

Crossing Relations of Some Diploid and Polyploid Species of Roses

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ROSA is one of the plant genera in which many polyploid species are known to occur. In the Texas Experiment Station's breeding program to secure improved rootstocks for roses a rather large number of interspecific crosses have been made or attempted. The relations apparent when the crosses among the diploid species alone were considered have been reported earlier (7). The present paper takes up the crossing relationships of species where forms observed or reported to be polyploid are involved. In these crosses the materials and methods have been identical in source and use as described for the studies among diploids alone (l.c.).

A considerable number of seedlings, of sufficient size for character study, have become available from the earlier crosses. Scrutiny of this F_1 material indicates that the great majority of the seedlings from the controlled crosses are true hybrids.

Where there is no evidence to the contrary we have considered the relative ease with which a cross is effected as indicating the degree of genetic affinity and relationship existing. Where the *Caninae* roses are seed parents, however, it is necessary, despite our seedling observations, to consider the possibility of the frequent heavy seed setting as being due to some type of apomixis and not to actual fertilization (6, 9, 10). The data are presented so as to show the compatibilities existing between different species, or between different groups of species. The data from the crosses have been considered when the parent species were grouped from each of the following three standpoints: (a) chromosome numbers; (b) taxonomic sections (following Rehder's classification) and; (c) genetic groups (following Hurst's system).

Results and Discussion

1. Parental Species Grouped According to Chromosome Numbers

For reported chromosome counts reference has been made to the papers of Blackburn (1), Erlanson (2), Hurst (4, 5, 6), Tackholm (9, 10), and to the chromosome lists of Tischler (12), and Gaiser (3). In many cases, and especially in instances of questionable material, chromosome counts have been made on our parental forms. Where there was good reason to doubt the authenticity of named material or of reported chromosome numbers of either parent of a cross, the cross is excluded from present consideration unless verification has been possible.

While report of the cytological findings will appear later we may note several points here which make for clarity in the tables. Among our three plants of *Rosa blanda* were two diploids ($2n = 14$) and one tetraploid ($2n = 28$). The tetraploid is not readily discernible from

Abreviations used in Tables I to X inclusive are as follows:

R. coriifolia Froebeli = cor. Froe.
R. damascena trigentipetala = dam. trig.
R. foetida bicolor = foet. bicol.
R. gallica conditorium = gall. cond.
R. gallica splendens = gall. spl.
R. hibernica gravesii = hibernica grav.
R. moschata floribunda = moschata flor.
R. multiflora cathayensis = mult. cathay.
R. multiflora chenault = mult. chenault
R. multiflora platyphylla = mult. plat.
R. multiflora upright = mult. upright
R. multiflora Welch = mult. Welch
R. spinosissima = sponosiss.
R. villosa recondita = villosa recond.
R. Wichuraiana (r'd) = Wichuraiana

TABLE I—CROSSES BETWEEN DIPLOID AND TETRAPLOID ROSE SPECIES

Cross No.	Seed Parent (Diploid)	Pollen Parent (Tetraploid)	No. Flowers Crossed	Per Cent Set	Seeds Per Hip		Per Cent Filled
					Crossed	O. P.	
-39	Beggeriana (5)†DD‡	foet. bicol. (1) BBDD	11	0	—	—	—
-39	Beggeriana (5)†DD‡	xanthina allard (1)	14	0	—	—	—
33-37	blanda B (5) DD	foet. bicol. (1) BBDD	39	8	5.7	22.0	26
52-37	blanda B (5) DD	gall. spl.** (2) AACC	29	62	22.4	22.0	102
53-37	blanda B (5) DD	saturata* (5) CCDD	45	24	27.5	22.0	125
-37	Giraldii (5) EE	foet. bicol. (1) BBDD	26	0	—	—	—
-37	Giraldii (5) EE	gall. spl.** (2) AACC	27	0	—	—	—
-37	Giraldii (5) EE	oxyodon DDEE	23	0	—	—	—
-37	Giraldii (5) EE	saturata (5) CCDD	47	2	—	—	—
-37	Giraldii (5) EE	saturata (5) CCDD	25	0	—	—	—
71-38	Helenae* (6) AA	foet. bicol. (1) BBDD	9	22	1.0	10.4	10
-39	Helenae* (6) AA	foet. bicol. (1) BBDD	29	—	—	—	—
60-38	Helenae* (6) AA	Manettii (7)	10	10	1.0	10.4	10
77-39	Helenae* (6) AA	xanthina allard (1)	13	15	1.0	10.4	10
20-37	lucida alba (4)	bella* (5) BBEE	20	40	17.1	47.2	36
46-38	lucida alba (4)	dam. trig.* (2) AACC	13	8	2.0	47.2	4
-38	lucida alba (4)	foet. bicol. (1) BBDD	15	0	—	—	—
39-39	lucida alba (4)	foet. bicol. (1) BBDD	12	25	4.7	47.2	10
18-37	lucida alba (4)	gallica (2) AACC	23	4	2.0	47.2	4
-38	lucida alba (4)	gall. spl.** (2) AACC	13	0	—	—	—
-38	lucida alba (4)	Manettii (7)	13	0	—	—	—
-37	lucida alba (4)	setipoda* (5) AAEE	23	0	—	—	—
49-38	lucida alba (4)	suffulta (5) CCDD	15	20	8.7	47.2	18
42-38	lucida alba (4)	xanthina allard (1)	15	13	3.5	47.2	7
40-39	lucida alba (4)	xanthina allard (1)	9	22	9.0	47.2	19
63-38	multiflora* (6) AA	foet. bicol. (1) BBDD	31	13	2.0	10.3	19
-38	mult. cathay. (6)AA	foet. bicol. (1) BBDD	17	0	—	—	—
-39	mult. cathay. (6)AA	foet. bicol. (1) BBDD	24	0	—	—	—
-39	mult. cathay. (6)AA	gall. cond.* (2) AACC	28	0	—	—	—
66-38	mult. cathay. (6)AA	Manettii (6)	20	5	2.0	10.5	19
-38	mult. cathay. (6)AA	moschata flor. (6)	11	0	—	—	—
52-39	mult. cathay. (6)AA	xanthina allard (1)	31	3	2.0	10.5	19
64-38	mult. chenault (6)	foet. bicol. (1) BBDD	25	4	2.0	9.3	22
-36	mult. Iowa	damas. trig.* (7) AACC	13	23	—	—	—
-36	mult. Iowa	foet. bicol. (1) BBDD	9	11	—	—	—
-36	mult. Iowa	gallica (2) AACC	8	0	—	—	—
-36	mult. Iowa	lucida (4) CCDD	12	0	—	—	—
-36	mult. Iowa	spinosissima* (1) BBCC	10	0	—	—	—
-39	mult. upright (6)AA	foet. bicol. (1) BBDD	24	0	—	—	—
63-39	mult. upright (6)AA	gall. cond.*(2) AACC	21	43	3.4	10.4	33
58-39	mult. upright (6)AA	xanthina allard (1)	23	13	1.7	10.4	16

*Chromosome number of this form accepted as reported by others; not counted by us.
**No chromosome count made or reported on this form, but all counts for this species and its varieties suggest the indicated number.
†Number in parenthesis refers to generic section, after Rehder (1940), see table.
‡Letters refer to Hurst's septet classification.

TABLE I—(*concluded*)

Cross No.	Seed Parent (Diploid)	Pollen Parent (Tetraploid)	No. Flowers Crossed	Per Cent Set	Seeds Per Hip		Per Cent Filled
					Crossed	O. P.	
–36	mult. Welch (6)AA	damas. trig.* (2) AACC	10	10	—	—	—
–36	mult. Welch (6)AA	foetida* (1) BBDD	10	0	—	—	—
–36	mult. Welch (6)AA	foet. bicol. (1) BBDD	8	0	—	—	—
–36	mult. Welch (6)AA	gallica (2) AACC	18	0	—	—	—
–37	odorata (7)	foet. bicol. (1) BBDD	53	0	—	—	—
–38	rugosa (5) CC	foet. bicol. (1) BBDD	8	0	—	—	—
–39	rugosa (5) CC	foet. bicol. (1) BBDD	12	0	—	—	—
–39	setigera A (6)	suffulta* (5)	14	0	—	—	—
–39	setigera A (6)	villosa recondita (3)	13	0	—	—	—
–39	setigera A (6)	xanthina allard (1)	15	0	—	—	—
–39	setigera C (6) AA	foet. bicol. (1) BBDD	15	0	—	—	—
–39	setigera C (6) AA	gall. cond. (2) AACC	15	0	—	—	—
–38	setigera (6) AA	centifolia (2) AACC	ca. 20	0	—	—	—
124–38	setigera (6) AA	damas. trig.* (2) AACC	ca. 20	15	5.7	4.9	116
119–38	setigera (6) AA	foet. bicol. (1) BBDD	ca. 20	5	1.0	4.9	20
–37	setigera (6) AA	gallica (2) AACC	31	0	—	—	—
–38	setigera (6) AA	gall. spl.** (2) AACC	ca. 20	0	—	—	—
121–38	setigera (6) AA	Manettii (7)	ca. 20	10	10.0	4.9	204
–38	setigera (6) AA	moschata flor. (6)	ca. 20	0	—	—	—
–38	setigera (6) AA	saturata* (5) CCDD	ca. 20	0	—	—	—
73–37	setigera (6) AA	setipoda* (5) AAEE	35	17	8.8	4.9	180
–38	setigera (6) AA	suffulta (5) CCDD	ca. 20	0	—	—	—
120–38	setigera (6) AA	xanthina allard (1)	ca. 20	10	2.0	4.9	41
–37	Soulieana (6) AA	foet. bicol. (1) BBDD	30	0	—	—	—
83–37	Soulieana (6) AA	foet. bicol. (1) BBDD	46	35	1.6	7.0	23
77–38	Soulieana (6) AA	foet. bicol. (1) BBDD	18	32	1.2	7.0	17
–39	Soulieana (6) AA	foet. bicol. (1) BBDD	20	0	—	—	—
77–37	Soulieana (6) AA	gallica (2) AACC	41	59	5.1	7.0	73
78–37	Soulieana (6) AA	gall. spl.** (2) AACC	30	37	3.8	7.0	54
–38	Soulieana (6) AA	Manettii (7)	20	0	—	—	—
74–37	Soulieana (6) AA	saturata* (5) CCDD	38	87	4.2	7.0	60
89–38	Soulieana (6) AA	suffulta* (5) CCDD	19	53	2.2	7.0	31
85–38	Soulieana (6) AA	xanthina allard (1)	24	38	4.0	7.0	43
–39	Soulieana (6) AA	xanthina allard (1)	20	0	—	—	—
–38	Wichuraiana (6) AA	centifolia (2) AACC	21	0	—	—	—
106–38	Wichuraiana (6) AA	damas. trig.* (2) AACC	17	35	2.7	23.85	11
97–38	Wichuraiana (6) AA	foetida (1) BBDD	17	12	1.5	23.85	6
–39	Wichuraiana (6) AA	foet. bicol. (1) BBDD	22	0	—	—	—
110–38	Wichuraiana (6) AA	gall. spl.** (2) AACC	17	29	1.8	23.85	8
92–39	Wichuraiana (6) AA	gall. cond.* (7) AACC	20	5	1.0	23.85	4
99–38	Wichuraiana (6) AA	Manettii (6)	19	16	2.7	23.85	11
–38	Wichuraiana (6) AA	saturata (5) CCDD	17	0	—	—	—
111–38	Wichuraiana (6) AA	suffulata* (5) CCDD	22	27	2.8	23.85	12
–39	Wichuraiana (6) AA	suffulata* (5) CCDD	19	0	—	—	—
102–38	Wichuraiana (6) AA	xanthina allard (1)	21	38	1.8	23.85	8
–39	Wichuraiana (6) AA	xanthina allard (1)	20	0	—	—	—
–37	Willmottiae (5) BB	foet. bicol. (1) BBDD	12	0	—	—	—
–15	Woodsii (1) DD	foet. bicol. (5) BBDD	15	7	2.0	15.3	13

*Chromosome number of this form accepted as reported by others; not counted by us.

**No chromosome count made or reported on this form, but all counts for this species and its varieties suggest the indicated number.

†Number in parenthesis refers to generic section, after Rehder (1940), see table.

‡Letters refer to Hurst's septet classification.

the diploids, and before the chromosome differences were noted some pollen mixtures of the three plants were used; data from such crosses were discarded for the purposes of this paper. In several cases chromosome differences were noted between species and their varietal forms, or between different varieties of the same species. As examples we may give the somatic chromosome numbers of the following: *Rosa lucida,* 28; *R. lucida alba,* 14; *R. moschata alba,* 14; *R. moschata floribunda,* 28; *R. recondita,* 14; *R. recondita villosa,* 28; and *R. xanthina,* 14; *R. xanthina allard,* 28. Such counts as these have been taken into consideration in preparing the tables.

TABLE II—CROSSES BETWEEN DIPLOID AND PENTAPLOID ROSE SPECIES

Cross No.	Seed Parent (Diploid)	Pollen Parent (Pentaploid)	No. Flowers Crossed	Per Cent Set	Seeds Per Hip		Per Cent Filled
					Crossed	O. P.	
-39	Beggeriana (5)†DD‡	cor. Froe.** (3) ACDDE	12	0	—	—	—
-39	Beggeriana (5)†DD‡	morica	11	0	—	—	—
-39	Helenae (6) AA	cor. Froe.** (3) ACDDE	13	0	—	—	—
44-38	lucida alba (4)	canina (3) AABDE	14	14	21.5	47.2	5
-37	lucida alba (4)	cor. Froe.** (3) ACDDE	31	0	—	—	—
-37	lucida alba (4)	mundi	18	0	—	—	—
-38	lucida alba (4)	mundi	13	0	—	—	—
-38	mult. cathay. (6)AA	Alberti (5)	27	0	—	—	—
-38	mult. cathay. (6)AA	canina* (3) AABDE	12	0	—	—	—
-39	mult. cathay. (6)AA	canina* (3) AABDE	24	0	—	—	—
-39	mult. cathay. (6)AA	cor. Froe.** (3) ACDDE	27	0	—	—	—
-39	mult. cathay. (6)AA	ferox* (3)	37	0	—	—	—
-36	mult. Iowa (6) AA	morica	7	0	—	—	—
-36	mult. Iowa (6) AA	mundi	6	0	—	—	—
59-39	mult. upright*(6)AA	canina* (3) AABDE	20	5	1.0	10.4	10
-36	mult. Welch (6)AA	mundi	10	0	—	—	—
122-38	setigera (2) AA	canina* (3) AABDE	ca. 20	5	1.0	4.9	20
-38	setigera (2) AA	morica	ca. 20	0	—	—	—
-38	setigera (2) AA	mundi	ca. 20	0	—	—	—
-39	setigera C (6) AA	cor. Froe.** (3) ACDDE	14	0	—	—	—
-39	setigera C (6) AA	morica	13	0	—	—	—
-39	setigera A (6)	mundi	13	0	—	—	—
-39	Soulieana (6) AA	Alberti (5)	20	0	—	—	—
-39	Soulieana (6) AA	banksiopsis (5)	20	0	—	—	—
86-38	Soulieana (6) AA	canina* (3) AABDE	23	17	1.3	7.0	18
-39	Soulieana (6) AA	canina* (3) AABDE	21	0	—	—	—
-37	Soulieana (6) AA	morica	37	0	—	—	—
-38	Soulieana (6) AA	morica	19	0	—	—	—
-37	Soulieana (6) AA	mundi	45	0	—	—	—
79-38	Soulieana (6) AA	mundi	23	9	1.0	7.0	14
85-39	Wichuraiana (6) AA	Alberti (5)	17	65	4.0	23.85	17
104-38	Wichuraiana (6) AA	canina* (3) AABDE	23	17	2.5	23.85	10
88-39	Wichuraiana (6) AA	canina* (3) AABDE	17	35	4.5	23.85	19
90-39	Wichuraiana (6) AA	cor. Froe.** (3) ACDDE	22	9	1.0	23.85	4
91-39	Wichuraiana (6) AA	ferox* (3)	10	20	2.5	23.85	10
95-39	Wichuraiana (6) AA	morica	22	5	3.0	23.85	13
113-38	Wichuraiana (6) AA	mundi	17	24	1.5	23.85	6
-37	Willmottiae (5) BB	morica	11	0	—	—	—
-37	Willmottiae (5) BB	mundi	15	0	—	—	—

*Chromosome number of this form accepted as reported by others; not counted by us.
**No chromosome count made or reported on this form, but all counts for this species and its varieties suggest the indicated number.
†Number in parenthesis refers to generic section, after Rehder (1940), see table.
‡Letters refer to Hurst's septet classification.

In roses the basic chromosome number is 7. In the crosses reported here, diploid, tetraploid, pentaploid, hexaploid and (probably) octoploid parents were used. Nineteen different combinations of chromosome numbers were attempted. *Rosa cinnamomea* was the only octoploid, or near-octoploid, species that was used, and exact counts on our plants of this form have not been made. Since the number is definitely very near 56, crosses involving this form are included for any possible additional information available from them.

Tables I to X inclusive record crosses attempted from 1936 through 1939. The crosses in these tables are arranged on the basis of respective chromosome numbers of seed and pollen parents. The left hand column of each table gives information relative to the number of the cross: if unsuccessful a number, as —36 or —39, records the year of the attempt; if successful a number has been assigned to the cross as 33–37 (see Table I, near top) which means this was the thirty-third successful cross to germinate in the year 1937. In the sixth column

TABLE III—CROSSES OF DIPLOID WITH HEXAPLOID AND OCTOPLOID ROSE SPECIES

Cross No.	Seed Parent (Diploid)	Pollen Parent	No. Flowers Crossed	Per Cent Set	Seeds Per Hip		Per Cent Filled
					Crossed	O. P.	
		2X × 6X					
-39	Beggeriana (5)†DD‡	hibernica glabra (1)	14	0	—	—	—
-39	Beggeriana (5)†DD‡	nutkana (5)AADDEE	13	0	—	—	—
-39	mult. cathay. (6)AA	hibernica glabra (1)	25	0	—	—	—
-36	mult. Iowa (6) AA	nutkana (5) AADDEE	10	0	—	—	—
-36	mult. Welch (6) AA	nutkana (5) AADDEE	16	0	—	—	—
-38	setigera (6) AA	nutkana (5) AADDEE	ca. 20	0	—	—	—
-39	setigera A (6) AA	nutkana (5) AADDEE	11	0	—	—	—
-39	setigera C (6) AA	hibernica gravesii (1)	15	0	—	—	—
-39	setigera C (6) AA	Macounii (5)	14	0	—	—	—
-37	Soulieana (6) AA	nutkana (5) AADDEE	30	0	—	—	—
78-38	Soulieana (6) AA	nutkana (5) AADDEE	18	11	1.0	7.0	14
93-39	Wichuraiana (6) AA	hibernica glabra (1)	21	14	1.0	23.85	4
-39	Wichuraiana (6) AA	hibernica gravesii (11)	19	0	—	—	—
94-39	Wichuraiana (6) AA	Macounii (5)	19	11	1.5	23.85	6
100-39	Wichuraiana (6) AA	nutkana (5) AADDEE	21	5	1.0	23.85	4
44-37	Woodsii (5) DD	nutkana (5) AADDEE	36	47	18.5	15.3	121
		2X × 8X (?)					
-39	mult. cathay. (6)†	cinnamomea (5)	25	0	—	—	—
-39	mult. cathay. (6)†	cinnamomea (5)	28	0	—	—	—
87-38	Soulieana (6)	cinnamomea (5)	17	12	1.5	7.0	21
-39	Soulieana (6)	cinnamomea (5)	21	0	—	—	—
105-38	Wichuraiana (6)	cinnamomea (5)	18	17	2.3	23.85	10
87-39	Wichuraiana (6)	cinnamomea (5)	19	5	1.0	23.85	4

*Chromosome number of this form accepted as reported by others; not counted by us.
**No chromosome count made or reported on this form, but all counts for this species and its varieties suggest the indicated number.
†Number in parenthesis refers to generic section, after Rehder (1940), see table.
‡Letters refer to Hurst's septet classification.

is found the average number of seeds per hip resulting from the controlled pollinations, while in the seventh column appear the average number of seeds in from 10 to 20 open-pollinated fruits of the seed parent. Number of seeds per hip in open-pollinated fruits were secured in 1939 except for *Rosa Beggeriana*, *R. gallica*, and *R. Woodsii* where 1940 counts were made. The figures in the last or "per cent filled" column are based on this average number of seeds in 1939 (or 1940) open-pollinated fruits as 100 per cent. This per cent is used as one measure of fertility for the various crosses. Doubtless the 100 per cent point of fill will show some, but very probably not marked, fluctuation from year to year.

As where diploids are crossed with diploids, some species set much more readily in interspecific crosses than others. Where diploid seed parents were crossed with polyploids in an appreciable number of cases *Rosa Soulieana* and *R. Wichuraiana* gave results above the average. For all diploids 46 per cent of species crosses and 14 per cent of pollinations set; for *Soulieana* these figures were 48 and 19.5 per cent respectively; and for *Wichuraiana* the per cents were 76 and 15. Among the tetraploid seed parents *gallica* (but not its varieties) was exceptional. For all tetraploid crosses per cents of crosses and of pollinations settings were 50 and 17 respectively; for *gallica* alone these figures were 79 and 37, much above the average in each case. The three pentaploid seed parents used all gave good results but *canina* was the best of the three in our crosses.

TABLE IV—Crosses Between Tetraploid and Diploid Rose Species

Cross No.	Seed Parent (Tetraploid)	Pollen Parent (Diploid)	No. Flowers Crossed	Per Cent Set	Seeds Per Hip		Per Cent Filled
					Crossed	O. P.	
-38	bella* (5)† BBEE‡	mult. chenault* (6) AA	12	0	—	—	—
-38	bella* (5)† BBEE‡	mult. Welch (6) AA	12	0	—	—	—
-37	bella* (5)† BBEE‡	odorata (7)	17	0	—	—	—
-37	blanda A (5)	multiflora Iowa (6)	49	0	—	—	—
-37	centifolia (2) AACC	odorata (7)	22	0	—	—	—
-37	damas. trig.* (7)AACC	abyssinica (6) AA	25	0	—	—	—
-39	damas. trig.* (7)AACC	gigantea* (7) AA	12	0	—	—	—
39-37	damas. trig.* (7)AACC	lucida alba (4)	25	36	13.1	10.3	127
-37	damas. trig.* (7)AACC	multiflora* (6) AA	35	0	—	—	—
-39	damas. trig.* (7)AACC	mult. chenault (6) AA	14	0	—	—	—
8-37	damas. trig.* (7)AACC	mult. Iowa (6) AA	34	3	1.0	10.3	10
-39	damas. trig.* (7)AACC	mult. upright (6) AA	12	0	—	—	—
-37	damas. trig.* (7)AACC	odorata (7)	27	0	—	—	—
-39	damas. trig.* (7)AACC	odorata (7)	13	0	—	—	—
66-39	damas. trig.* (7)AACC	rugosa (5) CC	15	67	7.8	10.3	76
34-37	damas. trig.* (7)AACC	Wichuraiana (6) AA	20	20	1.8	10.3	17
57-37	gallica (2) AACC	blanda (5) DD	21	81	26	25.0	104
24-38	gallica (2) AACC	Fendleri* (5) DD	15	27	16.2	25.0	65
30-38	gallica (2) AACC	Giraldii (5) EE	14	14	14.0	25.0	56
26-38	gallica (2) AACC	Hugonis* (1) BB	16	38	13.8	25.0	55
?-38	gallica (2) AACC	multiflora* (6) AA	19	58	29.7	25.0	119
-38	gallica (2) AACC	mult. chenault (6) AA	14	0	—	—	—
61-37	gallica (2) AACC	multiflora Iowa (6) AA	30	23	10.1	25.0	40
59-37	gallica (2) AACC	multiflora Welch (6)AA	28	43	18.7	25.0	75
54-37	gallica (2) AACC	odorata (7)	46	24	7.8	25.0	31
22-38	gallica (2) AACC	pisocarpa (5) DD	16	31	33.4	25.0	134
55-37	gallica (2) AACC	rugosa (5) CC	28	71	31.5	25.0	126
-38	gallica (2) AACC	Willmottiae (5) BB	16	0	—	—	—
32-37	gallica (2) AACC	Woodsii (5) DD	27	22	267.	25.0	—
29-38	gallica (2) AACC	xanthina (1) BB	13	46	13.8	25.0	55
-37	gall. spl.** (2)	Giraldii (5)	23	0	—	—	—
-36	gall. spl.** (2)	mult. cathay. (6)	9	0	—	—	—
-37	gall. spl.** (2)	mult. Iowa (6)	27	0	—	—	—
-37	gall. spl.** (2)	mult. platyphylla (6)	35	0	—	—	—
1-37	gall. spl.** (2)	pisocarpa (5)	26	8	6.5	5.8	112
10-37	gall. spl.** (2)	xanthina (1)	26	4	1	5.8	17
-38	lucida (4) CCDD	abyssinica (6) AA	12	0	—	—	—
-38	lucida (4) CCDD	mult. chenault (6) AA	14	0	—	—	—
2-37	lucida (4) CCDD	mult. Iowa (6) AA	19	5	8.	37.4	21
-38	lucida (4) CCDD	mult. upright (6) AA	16	0	—	—	—
-38	lucida (4) CCDD	mult. Welch (6) AA	14	0	—	—	—
-38	lucida (4) CCDD	odorata (7)	13	0	—	—	—
-37	lucida (4) CCDD	rugosa (5) CC	29	0	—	—	—
-37	lucida (4) CCDD	Wichuraiana (6) AA	22	0	—	—	—
-37	lucida (4) CCDD	xanthina (1) BB	14	0	—	—	—
72-39	moschata flor. (6)	mult. upright (6)	26	96	5.7	14.5	39
38-37	nitida (4) CC	lucida alba (4)	19	26	3.2	33.8	9
-37	nitida (4) CC	rugosa (5)	21	0	—	—	—
-37	oxyodon DDEE	mult. chenault (6) AA	13	0	—	—	—
-37	oxyodon DDEE	mult. Welch (6) AA	10	0	—	—	—
-37	oxyodon DDEE	odorata (7)	14	0	—	—	—
-37	setipoda* (5) AAEE	mult. cathay. (6) AA	49	0	—	—	—
-37	setipoda* (5) AAEE	mult. Iowa (6) AA	28	0	—	—	—
-37	setipoda* (5) AAEE	odorata (7)	32	0	—	—	—

*Chromosome number of this form accepted as reported by others; not counted by us.
**No chromosome count made or reported on this form, but all counts for this species and its varieties suggest the indicated number.
†Number in parenthesis refers to generic section, after Rehder (1940), see table.
‡Letters refer to Hurst's septet classification.

Table XI summarizes the crosses listed in Tables I to X, and in addition includes data from diploid by diploid crosses for completeness and comparison.

Effectiveness of Parents on Basis of Chromosome Grouping:—Comparing the figures of Table XI it would seem that on the basis of chromosome numbers the pentaploids are easily the best seed parents, while the tetraploids and diploids are close together in value, with good setting percentages both of interspecific combinations and

TABLE V—CROSSES BETWEEN TETRAPLOID ROSE SPECIES

Cross No.	Seed Parent	Pollen Parent	No. Flowers Crossed	Per Cent Set	Seeds Per Hip		Per Cent Filled
					Crossed	O. P.	
-39	blanda A (5)†	foet. bicol. (1)	23	0	—	—	—
48-37	blanda A (5)†	oxyodon	41	49	8.6	8.06	107
1-39	blanda A (5)†	xanthina allard (1)	12	8	1.0	8.06	12
-38	bella (5) BBEE‡	damas. trig.* (2) AACC	11	0	—	—	—
-37	bella (5) BBEE‡	foet. bicol. (1) BBDD	17	0	—	—	—
-38	bella (5) BBEE‡	Manettii (6)	13	0	—	—	—
-37	centifolia (2) AACC	foet. bicol. (1) BBDD	19	0	—	—	—
11-37	damas. trig.* (2) AACC	foet. bicol. (1)	17	12	1.0	10.3	10
-39	damas. trig.* (2) AACC	foet. bicol. (1)	13	0	—	—	—
-39	damas. trig.* (2) AACC	xanthina allard (1)	13	0	—	—	—
56-37	gallica (2) AACC	foet. bicol. (1) BBDD	32	22	10.4	25.0	40
-38	gallica (2) AACC	foet. bicol. (1) BBDD	17	0	—	—	—
60-37	gallica (2) AACC	oxyodon DDEE	21	67	23.0	25.0	92
62-37	gallica (2) AACC	saturata* (5) CCDD	29	69	33.4	25.0	134
27-38	gallica (2) AACC	suffulta (5) CCDD	19	42	28.2	25.0	113
28-38	gallica (2) AACC	xanthina allard (1)	13	54	7.3	25.0	—
51-38	lucida (4) CCDD	foet. bicol. (1) BBDD	12	8	2.0	37.4	5
-37	lucida (4) CCDD	gallica (2) AACC	28	0	—	—	—
-38	lucida (4) CCDD	Manettii (7)	15	0	—	—	—
37-37	lucida (4) CCDD	setipoda* (5) AAEE	26	85	34.5	37.4	92
-38	lucida (4) CCDD	xanthina allard (1)	15	0	—	—	—
-39	moschata flor. (6)	foet. bicol. (1) BBDD	29	0	—	—	—
-39	moschata flor. (6)	moschata flor. (6)	53	0	—	—	—
74-39	moschata flor. (6)	xanthina allard (1)	27	7	1.0	14.5	7
-37	nitida (4)	gallica (2)	13	0	—	—	—
31-37	nitida (4)	setipoda* (5)	23	35	14.9	33.8	40

*Chromosome number of this form accepted as reported by others; not counted by us.
†Number in parenthesis refers to generic section, after Rehder (1940), see table.
‡Letters refer to Hurst's septet classification.

TABLE VI—CROSSES OF TETRAPLOID WITH PENTAPLOID, HEXAPLOID AND OCTOPLOID (?) ROSE SPECIES

Cross No.	Seed Parent (Tetraploid)	Pollen Parent	No. Flowers Crossed	Per Cent Set	Seeds Per Hip		Per Cent Filled
					Crossed	O. P.	
		4X × 5X					
-39	damas. trig.*(2)†AACC	canina* (3) AABDE	14	0	—	—	—
-39	damas. trig.*(2)†AACC	cor. Froe.**(3)ACCDE	7	0	—	—	—
-38	gallica (2)	morica	14	7	2.0	25.0	8
-38	gallica (2)	mundi	17	30	8.0	25.0	32
-38	lucida (4) CCDD	canina* (3) AABDE	13	0	—	—	—
5-37	lucida (4) CCDD	coriifolia* (3) ACDDE	20	5	4.0	37.4	11
		4X × 6X					
70-39	damas. trig. (2) AACC	nutkana (5) AADDEE	15	80	10.5	10.3	102
58-37	gallica (2) AACC	nutkana (5) AADDEE	31	58	15.7	25.	63
		4X × 8X (?)					
-38	gallica (2)	Cinnamomea (5)	16	0	—	—	—

*Chromosome number of this form accepted as reported by others; not counted by us.
**No chromosome count made or reported on this form, but all counts for this species and its varieties suggest the indicated number.
†Number in parenthesis refers to generic section, after Rehder (1940), see table.
‡Letters refer to Hurst's septet classification.

total pollinations. Where seed parents were pentaploid about 80 per cent of the crosses set, where they are tetraploid about 50 per cent set, and where diploid about 40 per cent set (with one exception), regardless of the number of chromosomes in the pollen. This consistency would seem to speak for the significance of the figures. Hexaploids and octoploids can not be included in this group comparison because

TABLE VII—Crosses Between Pentaploid and Diploid Rose Species

Cross No.	Seed Parent (Pentaploid)	Pollen Parent (Diploid)	No. Flowers Crossed	Per Cent Set	Seeds Per Hip		Per Cent Filled
					Crossed	O. P.	
16–39	canina (3)† AABDE	blanda** (5)	14	43	2.2	21.8	10
17–39	canina (3) AABDE‡	fendleri (5) DD	16	13	1.0	21.8	5
19–39	canina (3) AABDE‡	gigantea (7) AA	12	83	8.9	21.8	41
–39	canina (3) AABDE‡	Giraldii (5) EE	12	0	—	—	—
73–38	canina (3) AABDE‡	mult. chenault (6) AA	12	8	3.0	21.8	14
21–39	canina (3) AABDE‡	mult. chenault (6) AA	14	29	1.8	21.8	8
–38	canina (3) AABDE‡	mult. upright (6) AA	10	0	—	—	—
6–39	canina (3) AABDE‡	mult. upright (6) AA	16	44	3.7	21.8	17
7–39	canina (3) AABDE‡	odorata (7)	22	77	2.5	21.8	11
–38	canina (3) AABDE‡	odorata (7)	11	0	—	—	—
13–39	canina (3) AABDE‡	rugosa (5) CC	26	73	10.4	21.8	48
–38	cor. froe.** (3) ACDDE	hugonis* BB (1)	11	—	—	—	—
36–37	cor. froe.** (3) ACDDE	lucida alba (4)	21	67	12.6	20.3	62
27–37	cor. froe.** (3) ACDDE	mult. cathay. (6) AA	13	15	4.0	20.3	20
–38	cor. froe.** (3) ACDDE	mult. chenault (6) AA	12	0	—	—	—
24–37	cor. froe.** (3) ACDDE	mult. Iowa (6) AA	17	6	5.0	20.3	25
34–38	cor. froe.** (3) ACDDE	mult. Iowa (6) AA	11	18	6.5	20.3	32
–38	cor. froe.** (3) ACDDE	mult. Welch (6) AA	12	0	—	—	—
3–37	cor. froe.** (3) ACDDE	odorata (7)	25	20	3.0	20.3	15
31–38	cor. froe.** (3) ACDDE	odorata (7)	11	9	1.0	20.3	5
26–37	cor. froe.** (3) ACDDE	rugosa (5) CC	9	22	3.0	20.3	15
33–38	cor. froe.** (3) ACDDE	rugosa alba (5) CC	12	25	1.3	20.3	6
14–37	cor. froe.** (3) ACDDE	Wichuraiana (6) AA	19	16	13.7	20.3	67
–38	cor. froe.** (3) ACDDE	xanthina (1) BB	13	0	—	—	—
–37	rubiginosa (3) ABBCD	abyssinica (6) AA	19	0	—	—	—
34–39	rubiginosa (3) ABBCD	gigantea (7) AA	17	29	14.4	27.5	52
21–37	rubiginosa (3) ABBCD	mult. cathay. (6) AA	19	21	23.2	27.5	84
26–39	rubiginosa (3) ABBCD	mult. cathay. (6) AA	21	95	11.2	27.5	41
27–39	rubiginosa (3) ABBCD	mult. chenault (6) AA	23	13	2.7	27.5	10
–37	rubiginosa (3) ABBCD	mult. Iowa (6) AA	24	0	—	—	—
28–39	rubiginosa (3) ABBCD	mult. upright (6) AA	17	47	4.4	27.5	16
–37	rubiginosa (3) ABBCD	odorata (7)	24	0	—	—	—
30–39	rubiginosa (3) ABBCD	odorata (7)	20	50	3.4	27.5	12
22–37	rubiginosa (3) ABBCD	Wichuraiana (6) AA	31	13	24	27.5	87

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**No chromosome count made or reported on this form, but all counts for this species and its varieties suggest the indicated number.
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‡Letters refer to Hurst's septet classification.

of the small number of crosses. It may be pointed out, however, that where hexaploid *Rosa nutkana* (Table IX) and octoploid *R. cinnamomea* (Table X) were used as seed parents in attempted crosses, setting percentages were very low.

If a significant per cent of maternals should appear among the future progeny from pentaploid seed parents, as might be expected from the work of Tackholm and of Hurst (l.c.), these seed parent ratings would need revision. On the basis of present data, however, pentaploids must be considered the outstanding seed parent chromosome group.

Thompson (11) and others have pointed out the interesting observation that in most plant genera interspecific crosses between parents with different chromosome numbers are more apt to be successful if the species with the higher chromosome number is used as the seed parent than in the case of the reciprocal crosses. The nature of the main aim of the present problem has resulted in only a small number of actual reciprocal species crosses in the present instance. However it is desirable from the practical plant breeding standpoint of securing adequate numbers of seedlings from which to select desirable material for testing, to know if the relative size of the chromosome number of

the two parents has any general tendency to influence results along this line.

By using the per cents in Table XI we may compare chromosome group crosses where the seed parents have identical, larger or smaller chromosome numbers than the pollen parents. If we omit the results of hexaploid by diploid crosses, which involved only five combinations, it is seen that in general where the seed parents had larger numbers of chromosomes there was a greater percentage of both crosses and pollinations setting, than in the other cases. But since it is apparent that this is due here to the "weight" of the number and fertility of crosses with pentaploid seed parents, we must conclude that it is not a significant fact, and that there are apparent no important effects due to proportional chromosome numbers of the parents.

TABLE VIII—Crosses of Pentaploid With Tetraploid, Pentaploid, Hexaploid and Octoploid (?) Rose Species

Cross No.	Seed Parent (Pentaploid)	Pollen Parent	No. Flowers Crossed	Per Cent Set	Seeds Per Hip		Per Cent Filled
					Crossed	O. P.	
		5X × 4X					
75–38	canina (3)† AABDE‡	foet. bicol. (1) BBDD	11	18	2.0	21.8	9
5–39	canina (3)† AABDE‡	foet. bicol. (1) BBDD	19	32	1.7	21.8	8
18–39	canina (3)† AABDE‡	gall. cond.* (2) AACC	12	100	10.5	21.8	48
74–38	canina (3)† AABDE‡	Manettii (7)	13	69	4.0	21.8	18
9–39	canina (3)† AABDE‡	xanthina allard (1)	15	20	1.7	21.8	8
12–37	cor. froe.** (3) ACDDE	foet. bicol. (1) BBDD	14	21	1.3	20.3	6
32–38	cor. froe.** (3) ACDDE	foet. bicol. (1) BBDD	12	8	1.0	20.3	5
–37	cor. froe.** (3) ACDDE	gallica splendens** (2)	17	0	—	—	—
37–38	cor. froe.** (3) ACDDE	suffulta (5) CCDD	11	55	12.8	20.3	63
36–38	cor. froe.** (3) ACDDE	xanthina allard (1)	13	15	3.5	20.3	17
23–37	rubiginosa (3) ABBCD	foet. bicol. (1) BBDD	25	12	6.3	27.5	23
31–39	rubiginosa (3) ABBCD	foet. bicol. (1) BBDD	21	43	3.2	27.5	12
–39	rubiginosa (3) ABBCD	xanthina allard (1)	21	0	—	—	—
		5X × 5X					
15–39	canina* (3) AABDE	Alberti (5)	16	50	12.1	21.8	56
20–39	canina* (3) AABDE	morica	13	69	—	—	—
23–39	canina* (3) AABDE	mundi	14	71	8.1	21.8	37
32–39	rubiginosa* (3) ABBCD	canina* (3) AABDE	23	70	18.6	27.5	68
–39	rubiginosa* (3) ABBCD	cor. froe.** (3) ACDDE	18	0	—	—	—
		5X × 6X					
22–39	canina (3) AABDE	hibernica glabra (1)	13	54	2.0	21.8	9
25–39	canina (3) AABDE	nutkana (5) AADDEE	12	92	18.0	21.8	83
		5X × 8X					
35–38	cor. froe.** (3)	cinnamomea (5)	12	50	4.3	20.3	21
33–39	rubiginosa (3)	cinnamomea (5)	15	87	23.3	27.5	85

*Chromosome number of this form accepted as reported by others; not counted by us.
**No chromosome count made or reported on this form, but all counts for this species and its varieties suggest the indicated number.
†Number in parenthesis refers to generic section, after Rehder (1940), see table.
‡Letters refer to Hurst's septet classification.

There is apparently less difference in the effectiveness of forms in the various groups as pollen parents, than as seed parents, although it is probably more difficult to evaluate species on a basis of pollen potency. Indications from Table XI are that tetraploids are most potent as a pollen group, while pentaploids, especially in per cent of pollinations setting, are least effective. Both of these indications are borne out, and somewhat strengthened, by considering the results of all crosses; that is, those including all combinations of these pollen groups

TABLE IX—CROSSES OF HEXAPLOID WITH DIPLOID, TETRAPLOID, AND OCTOPLOID (?) ROSE SPECIES

Cross No.	Seed Parent (Hexaploid)	Pollen Parent	No. Flowers Crossed	Per Cent Set	Seeds Per Hip		Per Cent Filled
					Crossed	O. P.	
		6X × 2X					
-38	nutkana (5)†AADDEE‡	Hugonis (1) BB	18	0	—	—	—
-38	nutkana (5)†AADDEE‡	multiflora (6) AA	17	0	—	—	—
-38	nutkana (5)†AADDEE‡	mult. chenault (6) AA	13	0	—	—	—
-37	nutkana (5)†AADDEE‡	mult. Iowa (6) AA	14	0	—	—	—
-38	nutkana (5)†AADDEE‡	mult. Iowa (6) AA	18	0	—	—	—
-37	nutkana (5)†AADDEE‡	mult. plat. (6) AA	15	0	—	—	—
-38	nutkana (5)†AADDEE‡	odorata (7)	21	0	—	—	—
-38	nutkana (5)†AADDEE‡	rugosa (5) CC	17	0	—	—	—
-37	nutkana (5)†AADDEE‡	Woodsii (5) DD	19	0	—	—	—
		6X × 4X					
-38	nutkana (5)	foet. bicol. (1) BBDD	13	0	—	—	—
-38	nutkana (5)	saturata (5) CCDD	10	0	—	—	—
-38	nutkana (5)	xanthina allard (1)	13	0	—	—	—
		6X × 8X (?)					
-38	nutkana (5)	Cinnamomea (5)	15	7	21.0	8.8	238

†Number in parenthesis refers to generic section, after Rehder (1940), see table.
‡Letters refer to Hurst's septet classification.

TABLE X—CROSSES OF OCTOPLOID (?) WITH DIPLOID AND TETRAPLOID ROSE SPECIES

Cross No.	Seed Parent (Octoploid)	Pollen Parent (Diploid)	No. Flowers Crossed	Per Cent Set	Seeds Per Hip		Per Cent Filled
					Crossed	O. P.	
		8X (?) × 2X					
-38	cinnamomea (5)†	mult. chenault (6)	13	0	—	—	—
-38	cinnamomea (5)†	mult. Iowa (6)	19	0	—	—	—
-38	cinnamomea (5)†	odorata (7)	17	0	—	—	—
-38	cinnamomea (5)†	rugosa (5)	14	0	—	—	—
		8X (?) × 4X					
-38	cinnamomea (5)	foetida bicolor (1)	17	0	—	—	—

†Number in parenthesis refers to generic section, after Rehder (1940), see table.

TABLE XI—SUMMARY OF CROSSES WITH PARENTS GROUPED ACCORDING TO CHROMOSOME NUMBERS, SHOWING PER CENTS OF SPECIES COMBINATIONS AND OF POLLINATIONS SETTING*

♂	2x		4x		5x		6x	
♀	Comb.	Poll.	Comb.	Poll.	Comb.	Poll.	Comb.	Poll.
2x..............	43	16	61	13	38	5	42	8
4x..............	49	14	50	20	50	8	—	—
5x..............	78	27	80	27	80	51	—	—
6x..............	0	0	—	—	—	—	—	—

*Only cases in which there were five or more species combinations made are considered here.

with hexaploid and octoploid seed parents, as well as those represented by the data of Table XI. The small number of crosses, as where seed parent groups were considered, does not allow a comparative rating for pollen potency of the two high polyploid groups. Reference to Tables III, VI, VIII and IX, however, will show that per cents of species combinations and of pollinations setting with hexaploid and octoploid pollen were high, and suggest that such forms may be especially valuable as pollen parents; additional crosses involving these chromosome forms are needed to confirm this.

Comparison of Results of Diploid Crosses With Crosses Involving Polyploids:—In crosses between diploids alone (7) 94 species combinations and 4,755 pollinations were attempted, with about a fourth more of each, or 118 and 6,008 respectively, where polyploids were used. Species combinations setting for all crosses was 48.5 per cent, for diploid crosses alone was 43 per cent, and for all crosses with polyploids was 54 per cent. Where pentaploids were eliminated these per cents were 45.5, 43, and 48 respectively. In per cent of pollinations setting, the diploid crosses were slightly above, and the polyploid crosses somewhat below the set for all crosses. For of all crosses 15.5 per cent, of diploid crosses 16 per cent, and of all polyploid crosses 15 per cent of pollinations gave sets. Where pentaploids were eliminated these per cents were 14, 15, and 12 respectively. The deviations of per cents for the two different groups of crosses from that for all crosses appear to be small enough to be negligible. The same may be said for differences in setting per cents where pentaploids are included and excluded from the data. Tests of statistical significance would appear to be meaningless here because of the number and nature of the factors affecting the results.

2. Results Considered on Basis of Taxonomic Relations of Crossed Species

The arrangement of species by generic sections set forth in Rehder's "Manual of Cultivated Trees and Shrubs" (8) has been followed here, as in our previous paper. In Tables I to X the number in parenthesis following a species name refers to the taxonomic section to which Rehder (8) refers the species in question. The names of the generic sections corresponding to these numbers may be found in Table XII.

TABLE XII—Rehder's Sections of Rosa

Second Edition (1940)	First Edition (1927)	Section	Second Edition (1940)
—	1	Simplicifoliae*	Subgenus Hulthemia
1	11	Pimpinellifoliae	Subgenus Eurosa
1	12	Luteae*	Combined with Pimpinellifoliae
1	13	Sericeae*	Combined with Pimpinellifoliae
2	7	Gallicanae	Subgenus Eurosa
3	8	Caninae	Subgenus Eurosa
4	9	Carolinae	Subgenus Eurosa
5	10	Cinnamomeae	Subgenus Eurosa
6	2	Synstylae	Subgenus Eurosa
7	6	Indicae	Subgenus Eurosa
8	3	Banksianae	Subgenus Eurosa
9	5	Laevigatae	Subgenus Eurosa
10	4	Bracteatae	Subgenus Eurosa
—	14	Minutifoliae*	Subgenus Hesperhodos
—	15	Microphyliae*	Subgenus Platyrhodon

*These sectional names not used in 1940 edition.

For completeness this table also lists the numbers of the sections as given in the first edition, and the subgeneric names and inclusions as presented in the last edition, of Rehder's work. *Rosa morica, R. mundi,* and *R. oxyodon,* which were used by us, are not included in Rehder's list. Data from these species is omitted from consideration in this section.

In Table XIII the partially summarized crossing data are arranged by numbers of the generic sections. The per cents of total species crosses and of total pollinations giving sets, and the per cent of fill of crossed hips — compared with open-pollinated hips — may all three be used as measures of crossing success in given individual crosses or groups of crosses.

From Table XIII it is apparent that crosses have been made between species within four different sections, *i.e.*, Caninae, Carolinae, Cinnamomeae and Synstylae. A glance at the columns indicating fertility

TABLE XIII—CROSSES PARTIALLY SUMMARIZED WITH SEED PARENT GROUPS ARRANGED ACCORDING TO REHDER'S SECTIONS

Sections Crossed	No. of Sp. Crosses	No. Giving Sets	Per Cent Setting	No. of Pollinations	No. of Sets	Per Cent Setting	Avg. Seeds Per Hip		Per Cent Filled
							Crossed	O. P.	
Gallicanae ×									
Pimpinellifoliae	7	5	71	179	29	16	10.0	20.5	49
Caninae	2	0	0	21	0	0	—	—	—
Carolinae	1	1	100	25	9	36	13.1	10.3	127
Cinnamomeae	13	11	85	311	124	40	23.1	20.9	111
Synstylae	4	3	75	302	35	12	18.0	19.1	94
Indicae	4	1	25	120	11	9	7.8	25.0	31
Caninae ×									
Pimpinellifoliae	9	6	67	187	40	21	6.9	22.4	31
Gallicanae	2	1	50	29	12	41	10.5	21.8	48
Caninae	2	1	50	41	16	39	18.6	27.5	68
Carolinae	1	1	100	21	14	67	12.6	20.3	62
Cinnamomeae	9	8	89	142	66	46	11.0	21.7	51
Synstylae	6	5	83	290	59	20	9.5	23.6	40
Indicae	6	6	100	155	57	37	5.1	22.5	23
Carolinae ×									
Pimpinellifoliae	5	3	60	92	8	9	5.0	44.7	11
Gallicanae	4	2	50	90	2	2	2.0	47.2	4
Caninae	4	2	50	78	3	4	15.7	42.3	37
Carolinae	1	1	100	19	5	26	3.2	33.8	9
Cinnamomeae	7	4	57	157	41	26	25.4	41.4	61
Synstylae	3	1	33	97	1	1	8.0	37.4	21
Indicae	3	0	0	41	0	0	—	—	—
Cinnamomeae ×									
Pimpinellifoliae	15	3	20	265	5	2	5.2	16.5	32
Gallicanae	3	1	33	67	18	27	22.4	22.0	102
Caninae	1	0	0	12	0	0	—	—	—
Cinnamomeae	9	4	44	241	30	12	22.2	14.2	156
Synstylae	5	0	0	259	0	0	—	—	—
Indicae	5	0	0	100	0	0	—	—	—
Synstylae ×									
Pimpinellifoliae	16	12	75	682	66	10	2.0	12.8	16
Gallicanae	10	6	60	350	63	18	4.0	14.4	28
Caninae	11	6	55	296	20	7	2.6	16.8	16
Carolinae	1	0	0	12	0	0	—	—	—
Cinnamomeae	20	10	50	575	77	13	3.8	17.7	21
Synstylae	4	1	25	110	25	23	5.7	14.5	39
Indicae	5	4	80	89	7	8	4.4	12.4	35
Indicae ×									
Pimpinellifoliae	1	0	0	53	0	0	—	—	—

by per cents of set and fill suggest that crosses between species in the same section are apt to be more successful than crosses between species in different sections. This is in agreement with our conclusion based on crosses among diploids. Thus where two crosses were made between species in the Caninae one of the two set, a good per cent of the pollinations set, and a better fill of set hips was realized than in any other crosses where Caninae species were used as seed parents.

In the single cross in which both species were in the Carolinae (*Rosa nitida* x *R. lucida alba,* Table IV) 26 per cent of the pollinations gave sets. This per cent was equalled in only one case in this seed group — where species of the Carolinae were pollinated by species of the Cinnamomeae — and it was much better than in other cases where the pollen parents were from different sections. The per cent of fill of the hips in this case was low, however.

Nine crosses were made between species belonging to the Cinnamomeae, and sets were secured from four of these. In only one case was the percentage of crosses giving sets exceeded when pollen parents from without the section were used, and here the excess was but slight. Per cent of pollinations giving sets, within Cinnamomeae, was low, but the per cent of fill of hips set was very high, much exceeding that of open pollinated hips.

Where crosses were made between species within the Synstylae it is seen that a larger per cent of pollinations have set, and a higher per cent of fill secured, than where crosses are made between seed species of this and pollen species of other sections. This is true even though only one cross of four attempted resulted in sets. The fact that the cross *Rosa moschata floribunda* x *R. multiflora upright* was so successful (Table IV) makes the high per cents in the last "per cent set" and the "per cent filled" columns appear to have a greater importance than is probably the actual case.

Value of Different Sections as Seed Parent Groups:—Table XIV is a summary of crosses with the seed parents in the different taxonomic sections being grouped. There are several points that have to be considered in evaluating the sections as seed parental groups. For one thing, as indicated by footnote three, since only one cross was involved with the Indicae its inclusion here should not necessarily

TABLE XIV—Summary of Data With Seed Parents Grouped in Taxonomic Sections

Sections of Seed Parent	No. of Sections of Pollen Parent	No. of Sp. Crosses	No. Giving Sets	Per Cent of Crosses Setting	No. of Pollinations	No. of Sets	Per Cent Setting	Per Cent Filled
Gallicanae......	7 (+3)*	34	24	71	1010	228	23	86
Caninae........	8 (+2)*	37	30	81	892	283**	32	41
Carolinae.......	8 (+1)*	28	13	46	605	60	10	46
Cinnamomeae...	7 (+3)*	43	9	21	1045	73	7	123
Synstylae.......	8 (+2)*	75	42	56	2366	265	11	22
Indicae.........	1	1†	0	0	53	0	0	—

*Figure in parenthesis refers to crosses with number of species not included by Rehder and of unestablished subgeneric section.

**274 sets used here in computing per cent filled, due to lack of seed number data in 9 cases.

†Insufficient for significance, included for completeness.

suggest it to be the least desirable seed parent section. Also, the large per cent of fill where species of the Cinnamomeae were seed parents should be somewhat discounted because a larger number of pollen parents of this same section were used than in the case of other sections.

When these points are considered together with the data an approximate evaluation as seed parental groups of the various sections used in our crosses would place Gallicanae and Caninae at the top as about equally desirable on the face of things, but with the crossing value of the latter possibly having to be discounted because of chance of apomictic effect in some cases; somewhat less valuable in our crosses were the three sections Carolinae, Cinnamomeae and Synstylae, all of about equal value, everything considered. Indicae can not be rated here on the basis of the present meager data with it.

3. Results Considered on Basis of Hurst's Grouping of Species

TABLE XV—Summary of Data With Pollen Parents Grouped in Taxonomic Sections

Sections of Pollen Parent	No. of Sections of Seed Parent	No. of Sp. Crosses	No. Giving Sets	Per Cent of Crosses Setting	No. of Pollinations	No. of Sets	Per Cent Setting	Per Cent Filled
Pimpinellifoliae..	6	53	29	55	1458	148	10	23
Gallicanae......	4	19	10	53	536	95	28	31
Caninae........	5	20	9	45	448	39	9	35
Carolinae.......	4	4	3	75	77	28	36	52
Cinnamomeae...	5	58	37	64	1426	338	24	71
Synstylae.......	5 (+1)*	23	10	43	1081	120	11	47
Indicae........	5 (+1)	24	11	46	519	75	14	27

*Figure in parenthesis refers to crosses with number of species not included by Rehder and of unestablished subgeneric section.

Hurst (4, 5) considers similar species to be geographical subspecies of a single empirical, or "differential septet", species. Subspecies of one of these species, according to the theory, all exhibit similar botanical characters due to the presence of the same septet, or septet combination, of chromosomes. There are five such basic sets, with a resultant five, and only five, diploid differential septet species. Hurst believes that evolution in roses has been by descent from an original decaploid ancestor and that the five diploid "genetic" species represent the ultimate in the rose genus, with a possible 206 additional, polyploid septet combinations, giving that many possible polyploid species of roses existing now or having existed in the past. His studies enabled him to assign definite septet formula to a number of the species used here. These have been indicated (by capital letters) in Tables I to X. Presumably the species most closely related genetically will cross with the greatest ease, barring complications such as the presence of incompatibility factors.

Consequently it has seemed advisable to arrange our data so that general crossing phenomena may be observed among the groups with the different septet formulae. This arrangement has been made in Table XVI, and suggests some interesting genetic relationships.

Where two or more septet combinations have been made, all seed groups with one or two A septets, except the hexaploid AADDEE,

TABLE XVI—COMPATIBILITY OF SPECIES AS ARRANGED ACCORDING TO HURST'S SYSTEM

	No. of Comb.	Per Cent Setting	No. of Poll.	Per Cent Setting	Per Cent Fill
AA×AA	28	46	756	14	36
BB	15	60	375	6	13
CC	7	57	220	5	12
DD	17	53	346	10	28
EE	4	50	125	2	14
AACC	17	53	350	18	32
AAEE	1	100	35	17	180
BBCC	1	0	10	0	—
BBDD	13	54	374	8	15
CCDD	7	43	167	29	29
AABDE	6	83	139	12	20
ACDDE	4	25	76	9	4
AADDEE	6	33	126	2	6
AACC×AA	11	45	243	14	94
BB	3	67	45	27	55
CC	2	100	43	70	133
DD	3	100	52	50	104
EE	1	100	14	14	56
BBDD	3	67	85	11	47
CCDD	2	100	48	58	128
DDEE	1	100	21	67	92
AABDE	1	0	14	0	—
ACCDE	1	0	7	0	—
AADDEE	2	100	46	65	77
AAEE×AA	2	0	77	0	—
AABDE×AA	3	100	64	34	26
CC	1	100	26	73	48
DD	1	100	16	13	5
EE	1	0	12	0	—
AACC	1	100	12	100	48
BBDD	1	100	30	27	8
AADDEE	1	100	12	92	83
ABBCD×AA	7	71	171	26	44
BBDD	2	100	46	26	15
AABDE	1	100	23	70	68
ACDDE	1	0	18	0	—
ACDDE×AA	6	67	84	10	41
BB	2	0	24	0	—
CC	2	100	21	24	10
BBDD	4	100	52	15	6
CCDD	1	100	11	55	63
AADDEE×AA	4	0	77	0	—
BB	1	0	18	0	—
CC	1	0	17	0	—
DD	1	0	19	0	—
BBDD	1	0	13	0	—
CCDD	1	0	10	0	—
BB×AA	1	100	15	7	—
BBDD	1	0	12	0	—
BBEE×AA	2	0	24	0	—
AACC	1	0	11	0	—
BBDD	1	0	17	0	—
CC×AA	1	0	13	0	—
CC	1	0	21	0	—
DD	1	100	11	9	69
BBDD	1	0	12	0	—
CCDD×AA	6	17	97	1	21
BB	1	0	14	0	—
CC	1	0	29	0	—
AACC	1	0	28	0	—
AAEE	1	100	26	85	92
BBDD	1	100	12	8	5
AABDE	1	0	13	0	—
ACDDE	1	100	20	5	11
DD×AA	3	100	88	31	51
BB	5	100	94	43	80
CC	2	100	38	79	114
DD	6	100	135	68	87
EE	1	100	36	56	93
AACC	1	100	29	62	102
BBDD	3	67	65	6	26
CCDD	1	100	45	24	125
CDDE	1	0	12	0	—
AADDEE	2	50	49	35	121

TABLE XVI—(*concluded*)

	No. of Comb.	Per Cent Setting	No. of Poll.	Per Cent Setting	Per Cent Fill
DDEE ×AA	2	0	23	0	—
EE ×CC	1	0	26	0	—
DD	1	0	47	0	—
AACC	1	0	27	0	—
BBDD	1	0	26	0	—
CCDD	1	100	72	1	—
DDEE	1	0	23	0	—

have given good percentages of set and fill. The third, fifth and sixth columns, Table XVI, bring this out. It may be observed however that where A and C septets are combined as in the seed groups AACC, ABBCD, and ACDDE that percentage of both set and fill is increased in the majority of cases where the same pollen group is concerned, over that of seed groups possessing A septets without C, or *vice versa*. The seed group AABDE, with comparatively few species combinations, is somewhat of an exception in that the set here was as good as in AC combination. In addition, where two A septets are present in both the seed and the pollen parents the accelerating effect of C, when present in the former, is not so obvious. This increased compatibility may be due to acceleration of pollen tube growth or some related phenomena. It is also apparent from the table that where seed groups with the formula DD have been used that compatibility and fertility, with various pollen groups, is good.

Numbers of combinations and pollinations with the remaining seed groups are probably not large enough to give much significance to other observed trends, such as the apparent depressing effect of C on DD septets, so far as compatibilities and fertilities of various groups are concerned. Some positive tendencies and affinities are also indicated with certain of the septet combinations in the pollen groups, but these are not brought out definitely enough by present data to warrant discussion at this time.

The data presented in Table XVI have been checked to see if crosses involving polyploids in which the pollen contained septets identical with those of the seed parent were any more prolific than where such septets were different in the different parents. When the data are considered either separately (as in Table XVI), or are combined and averaged, fertility is apparently not increased by pollinating with forms having (one or more) septets corresponding to those reported for the seed parent (although results from use of pollen carrying AA septets on seed forms with this group suggests an exception).

A partial explanation of the productive and fertile results of seed species with septet formulae AA, AACC, and DD may be furnished by the data on which Table XVII is based. This table, which includes only the species which Rehder (1940) describes in detail, is substantiated by available data from all species. It shows that the Gallicanae is mainly a tetraploid, AACC section; and that the Synstylae is essentially a diploid, AA section. Also, while not shown so clearly by the table, the Carolinae is predominantly a diploid DD section;

TABLE XVII—OCCURRENCE OF CHROMOSOME NUMBERS AND OF HURST'S SEPTETS IN DIFFERENT TAXONOMIC SECTIONS

Taxonomic Section	No. of Species Described by Rehder 1940	No. of These Sp. on Which Data are Available	Chromosome Numbers†	Septets Represented†
Pimpinellifoliae	7	5	28, 14	*BB**, DD, CC
Gallicanae	4	4	*28*‡	*AACC**
Caninae	8	8	35**, 28	A, D, E, B, C
Carolinae	5	5	*14***, 28‡	*DD**, AA, CC
Cinnamomeae	25	24	14, 28, 42, 56	DD, EE, BB, AA, CC
Synstylae	13	12	*14*‡	*AA**
Indicae	4	2	14–42	AA

†Where more than one number or one septet combination has been reported for species of a section, such numbers or septets are arranged, from left to right, in order of their frequency of occurrence.
‡One form in which this number occurs has also been reported as having a higher number.
*A preponderance of the species possess these septets.
**A preponderance of the species have this chromosome number.

four of the five species have chromosome numbers of 14 (28 has also been reported for two of these same ones), and the four with given septet formula have reported DD septets alone or in combination. The Caninae, composed of the cytologically irregular species, is made up principally of pentaploid forms with some tetraploid and hexaploid ones, having all of Hurst's septets represented among the species but with A septets occurring most frequently especially in duplicate condition. Members of the Caninae used as seed parents in our crosses possessed either AA or AC septets, in combination with others. In the other sections there is a more even distribution of chromosome numbers, of septet occurrence, or of both — as is decidedly the case in the Cinnamomeae.

It appears significant that the septet formulae possessed by the majority of the most prolific and fertile seed parent species (*Rosa gallica, R. Soulieana, R. wichuriana,* and probably including the pentaploid Caninae species, but with fertile *R. blanda,* in the Cinnamomeae with a DD formula, offering an exception) are characteristic of the taxonomic sections whose species most resemble each other with respect to chromosome number, as well as septet formulae. This would suggest that in sections as the Gallicanae and the Synstylae that the species are on the whole not only more closely related to each other than in the sections where more variation occurs, but also that this closer relationship is due to a genetic condition, possibly greater genic homozygosity, which may permit of greater chance for crossing compatibilities and fertility. While some species both within and without these sections may be pointed to as exceptions they do not hide the tendency for sections with least variation in chromosome numbers and septets to show a general effect of this in the crossing relationships of included species. Further studies should throw additional light on this point.

SUMMARY AND CONCLUSIONS

Results of 6,008 pollinations including 118 different attempted species crosses are reported. The data are considered here when the parental species were grouped according to (a) chromosome numbers,

(b) taxonomic sections, and (c) genetic groups (Hurst's). Most comparisons were made on group bases as being more productive of useful conclusions.

Pentaploids, as a group, were the most fertile seed parents, followed by tetraploids and diploids, which were of about equal worth. No effect of apomixis on results from our pentaploid crosses has been revealed to date. Value of a seed parent was but little affected by having its chromosome number equal, larger, or smaller than that of pollen parents. Tetraploids were somewhat the most valuable pollenizers as a group. The comparatively small number of combinations and pollinations with hexaploids and octoploids suggests these to be excellent pollen but poor seed groups.

As in crosses among diploids per cents of sets and of hip fill indicated greater probability of successful crosses occurring between species belonging to the same taxonomic section than when the species belong to different sections. Species belonging to the Gallicanae and the Caninae were most productive as seed parents. Forms belonging to sections Carolinae and Cinnamomeae were most effective, as a group, for pollen.

The crosses were examined on the basis of Hurst's septet grouping of species. Seed parents with AA, AACC, and DD septets were fertile groups, with the fertility of AA septets usually being increased by the presence of CC. In general similar septets in seed and pollen groups did not increase crossing fertility over cases of combining completely dissimilar septets. There is a tendency for the most fertile septet (seed) groups to fall in the taxonomic sections showing least cytogenetic variation.

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Effect of Some Spray Materials on the Apparent Photosynthetic Rate of the Greenhouse Rose

By ALEX LAURIE and D. J. WITT, *Ohio Agricultural Experiment Station, Wooster, Ohio*

MANY investigations of the injury caused by spray materials applied to foliage of horticultural plants have been conducted, but very little has ever been done on the rose. A study was made of the effect on apparent photosynthesis of some of the more common commercial sprays used by florists to combat red spider on the greenhouse rose. Variety Better Times was used.

A modification of the pump diagrammed by Childers and Brody (1) was used and the apparent photosynthesis was determined by the method described by Heinicke and Hoffman (2). Two and one-half hour runs were made daily on six sprayed leaves and four unsprayed leaves. A 3- or 4-day relationship between the two sets of leaves was made prior to spraying. Light and temperature readings were taken at the beginning, middle, and termination of each run and then averaged. Sprays were applied with a hand atomizer in late afternoon. Cellophane bags were placed over the five leaflet leaves, as they are more satisfactory than leaf cups for the leaf of the rose plant. For each spray material, three runs were made under varying seasonal environment from January to July. The expected rate of apparent photosynthesis was determined as follows. The apparent rates of photosynthesis for the check and sprayed leaves were averaged separately to establish a relationship. Dividing the average of the sprayed leaves by the average of the check leaves and multiplying the quotient by 100 gave the expected rate. The per cent expected rate was obtained by dividing the daily apparent rates of the sprayed leaves by the daily apparent rate of the check leaves and multiplying the quotient by 100. Dividing this product by the expected rate and multiplying the resulting quotient by 100 gives the per cent expected rate.

Table I shows typical results obtained from a run using Hitox, a rotenone, pyrethrum and oil spray, at 1–200. Following the spray application there was a gradual reduction in the expected rate of photosynthesis, the most severe reduction of 21 per cent occurring on the sixth day. Recovery occurred on the thirteenth day after application of the spray. In another run a second spraying was made 13 days after a previous spray had been applied and a 35 per cent reduction of the expected rate of apparent photosynthesis occurred. Recovery was observed 16 days following the second application.

Righto at 1–400, a pyrethrum and rotenone spray was noted to reduce the expected rate of apparent photosynthesis. The initial reduction from three determinations varied between 14 and 24 per cent. A second spray application made 10 days after the first spray reduced the rate 36 per cent. Recovery was rapid with this spray material, usually only 1 week elapsing before normal relationships were observed.

A trade name material, 157, consisting of rotenone with glycerol reduced the rate of apparent photosynthesis 20 to 30 per cent and after

TABLE I—THE EFFECT OF HITOX AT 1–200 ON THE RATE OF APPARENT PHOTOSYNTHESIS OF ROSE LEAVES

Date 1940	Rate of Apparent Photosynthesis in $MgCO_2/100\ Cm^2/Hr$		Per Cent of Expected Rate of Sprayed Leaves	CO_2 Content of the Air (Mg/Ft^3)	Light Intensity (F. C.)	Air Temperature (Degrees F)
	Check	Sprayed				
May 19	8.0	8.7	108.5a*	15.5	1490	72
May 20	10.9	11.6	106.1b	14.7	2670	90
May 21	9.3	10.1	108.6c	14.1	1770	80
Average	—	—	107.7**	—	—	—
May 22	7.8	7.7	91.5†	17.1	2470	88
May 23	7.4	7.4	92.6	16.4	638	70
May 24	6.2	5.6	84.3	15.4	216	66
May 25	8.0	7.4	86.0	15.4	878	80
May 26	8.8	7.9	83.2	14.9	2365	70
May 27	9.3	7.9	79.0	16.0	1932	64
May 28	7.9	6.7	79.6	17.3	620	68
May 29	6.9	7.1	95.5	15.7	1022	70
May 30	10.7	9.5	82.2	17.4	1145	69
May 31	9.5	10.1	98.8	15.8	980	73
June 1	10.8	10.5	90.3	18.1	660	76
June 2	6.5	6.5	92.9	15.0	4425	96
June 3	9.1	10.1	102.8	18.3	1975	80

$$* \left\{ \frac{\text{Daily rate of sprayed leaves}}{\text{Daily rate of check leaves}} \times 100 \right\}$$

**Average of a, b, and c.

$$\dagger \frac{\dfrac{\text{Daily rate of sprayed leaves}}{\text{Daily rate of check leaves}} \times 100}{107.7} \times 100$$

7 days with two determinations and 21 days with one run, recovery had not occurred.

With Red Arrow at 1–400, a pyrethrum and soap spray, a reduction of 22 per cent occurred the first day following application. The temperature rose to 92 degrees F on the fifth day and a 40 per cent reduction was observed. Eleven days after the spray was applied again at 20 per cent reduction still existed.

With all sprays tested a marked reduction occurred the first day following application. This reduction usually persisted for at least 5 or 6 days before a gradual recovery took place. A second application of spray material produced a similar but usually a more drastic reduction than the first application. Recovery often occurred just as rapidly, however. With some spray materials no recovery occurred during the time interval the experiment was run though it is to be assumed that recovery would eventually occur.

There was no visible injury either as scorching, chlorosis, and so on from any of the materials whether applied once or twice, however, reductions in the apparent photosynthesis ranging from 12 to 36 per cent, depending upon the spray material, were observed. It was not possible from these studies to determine whether the oil, soap, glycerine, rotenone, or pyrethrum were causing the reduction in the apparent photosynthetic rate.

Further tests are being run to determine the causal factor in reduction of photosynthesis and the effect of continuous use of the materials on flower production.

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Hardiness Zones for Woody Ornamentals in New York State

By JOHN F. CORNMAN, *Cornell University, Ithaca, N. Y.*

ABSTRACT

This material will be published in full as a bulletin by the Cornell Experiment Station.

IT WAS the purpose of this study to determine more accurately the boundaries of the various planting zones of the state as shown by the reactions of plants, rather than from weather statistics and to record the type and degree of winter injury occurring on a number of woody ornamentals.

Data for use in establishing zone lines and in determining the relative hardiness of the various species were collected by a field survey, consultations, and questionnaires. Representative stations were visited in all areas of the state. As many plants as possible were observed in the field with particular attention being paid to about 100 of the more common kinds reaching their northern limit of hardiness in the state.

It seemed desirable to introduce a somewhat different concept of the term hardiness, for a plant is often useful in the landscape even though it occasionally suffers winter injury. A woody ornamental may grow fairly well in a location, but if it is injured during the winter just enough to destroy the desirable feature for which it was planted, it does not fulfil its purpose in the landscape. For these reasons it is necessary to consider a plant usefully hardy as an ornamental only when, with a reasonable amount of care, it is fairly dependable in producing the flowers, fruit, foliage, or other feature expected of it.

A map showing six zones of hardiness for woody ornamentals has been prepared. While these zones differ from each other in climate, they were established primarily because of differences in hardiness of the plant materials studied.

It seems reasonable that for New York State the recommendations of Wyman and Rehder will be more accurate if used in connection with the proposed detailed map. In this application zone 1 corresponds roughly to zone VI, zone 2 to zone V, zone 4 to zone IV and zones 5 and 6 to zone III. Thus zone 3 is transitional between zones V and IV.

The hardiness map developed as a result of this study is not to be considered as final, for as more information becomes available certain changes will undoubtedly be indicated. However, it is believed that this map is an improvement in our understanding of the various hardiness zones for woody ornamentals in New York.

Two Colchicine-Induced Polyploids of the Greenhouse Chrysanthemum and Their Progeny

By Charles Weddle, *Cornell University, Ithaca, N. Y.*

EARLIER workers with colchicine have pointed to floriculture as the field wherein lay the greatest possibilities for improving economic plants by inducing chromosome doubling. Muntzing (3) and Blakeslee and Avery (1) point out that polyploidy is known to have been a factor in the origin of a large portion of the desirable varieties of fruits, vegetables, and flowers. The theoretical possibilities of inducing chromosome doubling are great. In the field of floriculture Nebel and Ruttle (4) have led the way with the production of tetraploid marigolds and snapdragons. Emsweller and Brierley (2) have contributed tetraploid lilies. In these cases the tetraploids promise to have greater economic value.

Chrysanthemum morifolium normally has 54 somatic chromosomes (5). It was thought to be a good subject for preliminary trials at Cornell because it is easily propagated vegetatively, so that any resulting varieties could be propagated by cuttings. The great heterozygosity of the chrysanthemum suggested that further chromosome doubling might be a means of getting true breeding strains, since this was already being attempted by inbreeding.

Accordingly, in the spring of 1939 seedlings from crosses between commercial varieties were treated with colchicine. At the time of transplanting 143 seedlings were treated by inverting their growing points in a .16 per cent solution for 6 hours and 100 seedlings were likewise immersed for 8 hours. To the growing points of 88 plants a single application of Warmke and Blakeslee's .2 per cent lanolin emulsion was given. Another lot of 40 seedlings was treated with the .4 per cent emulsion. The plants were grown in pots for close observation.

Results

Several of the plants produced tetraploid sectors, but only two produced tetraploid flowering stems. (The 54-chromosome form, although already hexaploid, the base number being 9, will be considered diploid and the 108-chromosome type will be considered tetraploid). Both tetraploid plants arose from seedlings given the 6-hour treatment in the .16 per cent solution. The first tetraploid T1 plant was a seedling of the cross Melba x Blanche and the second plant T2 a seedling of the cross Sunshine x Blanche. Plant T1 had one diploid stem which fortunately produced a flower head, furnishing pollen for comparison. Plant T2 produced no diploid shoots.

Size of guard cells and size of pollen grains were used as criteria of tetraploidy until sufficient material was available for cytological observations. These measurements, which proved to be quite reliable indices, are listed in Table I.

The shape of the pollen grains also was affected, the oval shape of the diploid form being changed to a somewhat roughly cubical or pyramidial shape. The grains appeared square or triangular when viewed through the microscope.

TABLE I—CHROMOSOME NUMBER, POLLEN GRAIN SIZE, AND STOMATA LENGTH

Plant	Number of Chromosomes	Average Diameter Pollen Grains (Microns)	Average Length of Stomata (Microns)
Tetraploid No. I	108*	105	119
Normal Stem P. I	54	78	91
Tetraploid No. II	108*	105	100

*Estimated.

Plant T1 was quite dwarf with strong short stems. The flowers of both normal and tetraploid stems were light phlox pink, and single, having two rows of quilled and spoon rays. Quilled rays are those which are tubular for their entire length while spoon rays are those which are tubular for only about half their length. The leaves of the three tetraploid stems were shorter, thicker and less deeply cut than the diploid leaves. The petioles of the tetraploid stems were shorter and thicker and the leaves, petioles and stems were more pubescent.

The second tetraploid plant (T2) was large, being about 4 feet tall. The leaves were even more pubescent than those of plant T1. The stems were not as strong in comparison. The flowers were large with three rows of flat, thick, creamy white rays. This thickness of the rays was very noticeable, giving great substance to the flowers. The flowers of both tetraploid plants kept fresh on the plant for over a month.

Flowers of both tetraploid plants were self pollinated. Forty-five tetraploid seedlings were obtained from plant T1 and 10 tetraploid and 2 diploid seedlings from T2. Both parent plants and the diploid stem from plant T1 were propagated by cuttings. When flower buds were of sufficient size chromosome studies were made, and the tetraploid nature of the parent and seedling plant was confirmed. Accurate cytological analysis is extremely difficult for the diploid chrysanthemums and practically impossible for the tetraploid forms because of the large numbers and irregular pairing of chromosomes. This, therefore, was not attempted. The relative numbers, however, were fairly easy to determine. The diploid number is 54 $\pm$ 1 and therefore the estimated tetraploid number is 108. The most striking cytological feature was the frequency of polyspory in the tetraploids, the production of more than four pollen grains from a single microspore mother cell. This is thought to be responsible for the variability in the selfed progeny. Similar irregularities in mitosis could cause the frequent somatic mutations that were observed in the tetraploid plants.

The progenies of the tetraploids were remarkably true for flower type, the progeny of T1 having all single flowers with quilled and spoon rays. There was some variation in amount and degree of quilling, however. Color varied considerably in the progeny of T1 but was quite constant in the 10 tetraploid progeny of T2. In the progeny of plant T1 there were seven white-flowered plants, 34 pink, one purple, six yellow and one bronze flowered. The progeny of plant T2 were all white or creamy white.

A few somatic color mutations were observed in the progeny of plant T1, but they occurred late in the development of the flower and never involved as much as a single ray floret. In plant T2, however, every plant but one mutated in one or more flowers to yellow and in one plant sported both to yellow and purple. These color changes were simultaneous in three plants with changes in flower type, one such change was from the flat reflex type of rays to the incurved spoon type and involved whole flowers.

Summary and Conclusions

In these experiments little net improvement resulted from induced polyploidy in the chrysanthemum. The improvement in substance and keeping qualities of flowers, however, is noteworthy. Tetraploid plants might be valuable as novelty pot plants. Variation in the progeny of the parent tetraploids and the frequent somatic mutations are probably due to irregularities in meiosis and mitosis respectively. Selections from the progeny of the two tetraploids will be inbred to determine if it is possible to stabilize them and to establish true breeding varieties. A number of plants are being tested for cold hardiness.

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Budding Ornamental Malus on the Malling Rootstocks[1]

By J. K. Shaw, *Massachusetts State College, Amherst, Mass.*

THE introduction of the Malling clonal rootstocks suggests the possibility of growing ornamental flowering crabs of various sizes for use in landscape compositions. In August, 1938, varying numbers of 10 kinds of flowering crabs were budded on nine Malling rootstocks. Some of the combinations were successful and some failed entirely. The results are shown in Table I. The nomenclature follows that of Graves (1), which is based mostly on that of Rehder (2). Rootstocks X, XII, XIII and XVI have very slight or no dwarfing effect; the others are more or less distinctly dwarfing.

All but three kinds failed completely on Malling IX and most of them succeeded poorly on the dwarfing rootstocks. Even when they started well the first year, many failed the second. *Malus ioensis plena* (Bechtel crab) made a poor record on all rootstocks. Rootstocks of Malling IX were rebudded with Bechtel crab in 1939 and all buds failed. Upshall (3) reported failure of Bechtel on Malling IX. *M. hupehensis* (*M. theifera*) buds did not grow on most dwarfing rootstocks.

Most of the trees that made good growth the first year continued to do so through the second year and there are few signs of a dwarfing effect, which is much the way that comestible varieties behave on these rootstocks. *M. atrosanguinea* and *M. floribunda* killed back rather severely, especially on Malling XII.

These results should be taken only as suggestive. The work must be repeated with larger numbers and under varying conditions before it can be said that these failures represent incompatibilities between the ornamental Malus and these clonal rootstocks. It does suggest, however, that care must be used in selecting stock and scion combinations when one desires small flowering crabs for landscape purposes.

TABLE I—Results from Budding Ornamental Malus on Malling Clonal Rootstocks

Malling Stocks No. Buds Set	I 10		II 5		III 8		IV 6		IX 10		X 10		XII 8		XIII 10		XVI 5	
	a*	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
Arnoldiana	50	40	100	80	0	0	33	33	0	0	50	40	37	37	70	50	80	60
Atrosanguinea	40	30	60	20	0	0	33	33	0	0	50	50	88	88	80	80	40	40
Floribunda	30	30	60	60	37	37	33	33	0	0	50	50	88	88	60	50	60	40
Hupehensis (theifera)	40	40	0	0	0	0	0	0	0	0	10	10	75	63	70	50	40	40
Ioensis plena	20	10	40	0	0	0	0	0	0	0	50	0	37	13	80	10	40	0
Purpurea eleyi	20	20	0	0	25	12	0	0	0	0	70	50	13	13	60	50	80	80
Sargenti	20	20	0	0	0	0	50	17	0	0	50	20	75	75	70	70	20	20
Scheideckeri	40	40	0	0	37	37	50	50	30	20	90	70	88	75	100	90	80	80
Spectabilis	80	80	60	60	63	63	84	84	30	10	100	100	75	75	90	90	40	40
Toringoides	70	70	20	20	0	0	33	17	90	80	100	90	63	63	60	40	40	40

*a = 1-year trees as percentage of buds set. b = 2-year trees as percentage of buds set.

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[1]Contribution No. 395 of the Massachusetts Agricultural Experiment Station.

The Effect of Vitamin B_1 on Some Ornamental Greenhouse Plants

By Alex Laurie and D. C. Kiplinger, *Ohio State University, Columbus, Ohio*

Abstract

A full report of this paper will be published in the *Ohio Agricultural Experiment Station Bimonthly Bulletin* for March-April, 1941.

SINCE the discovery that vitamin B_1 is necessary for the growth of plants, popular horticultural literature has been filled with articles and advertisements of its beneficial effects. Many of the claims were fantastic beyond reason; *i.e.* unbelievably large flowers may be produced in an amazingly short time by simply applying vitamin B_1. The tests here reported were conducted to determine its practical value for commercial florists.

The soil used was composted for the greenhouse, and each crop was given a specific soil mixture which is considered best for optimum growth.

The solutions were applied weekly in water at a pH of 9.8 and 4.8 at a concentration of 0.05 milligrams of vitamin B_1 per gallon. Root systems were soaked in an alkaline solution of 5 milligrams of vitamin B_1 per gallon. Between applications the plants were watered with alkaline tap water.

On chlorotic gardenias vitamin B_1 applications were no more effective than allowing the plants to re-establish a root system by carrying them on the dry side. Rooted gardenia cuttings showed no growth differences after 17 weeks of treatment.

Roses grown in pots in the greenhouse and in a cloth house treated with vitamin B_1 failed to produce longer stems or larger flowers than the check plants. Treatment of pot chrysanthemums showed no differences in growth or flowering when treated with vitamin B_1 for 4 months. Spraying with B_1 on the foliage of chrysanthemums for 4 months was not beneficial.

Asters and pompon chrysanthemums in a cloth house were not benefitted by treatment. Kentucky Blue Grass produced clippings of greater dry weight when treated but these differences were not manifested in top growth.

Soaking root systems of roses in vitamin B_1 failed to prevent wilting. Cutback gardenias did not resume growth more rapidly when treated with vitamin B_1.

Applications of vitamin B_1 to chrysanthemums and gardenias in gravel culture were not beneficial.

As a result of these tests it has been concluded that applications of vitamin B_1 either to soil-grown plants or plants in gravel culture have failed to justify its use for practical purposes.

The Effect of Light Intensity on Response of Euphorbia Pulcherrima and Euphorbia Fulgens to Photoperiod and Temperature

By Kenneth Post, *Cornell University, Ithaca, N. Y.*

POINSETTIAS (*Euphorbia pulcherrima*) and *E. fulgens* have been made to flower in advance of the normal flowering period by reducing the length of day during summer. The normal date when the days are the proper length for bud formation at Ithaca, New York has been determined as October 10 to 20 (2). Previous unpublished data and the work of Roberts and Struckmeyer (3) show that temperatures above 65 degrees, during the period of bud initiation, prevented bud formation.

The early work of Garner and Allard (1) with poinsettia showed it could be made to flower during summer by giving the proper photoperiod. Probably the minimum temperature was above 65 degrees most of the time during these experiments.

Reducing the length of day during July and August at Ithaca has produced flowering. Growers of poinsettias have observed that plants placed in poorly lighted positions in the greenhouse failed to form flower buds even though the night temperature was correct (55 to 65 degrees). Short day treatment of Poinsettias and Euphorbia in a Long Island greenhouse, which was poorly lighted during the summer of 1939, failed to cause flowering. The treatment was carried out in the same manner as one at Ithaca where flowering occurred.

Plants grown at Ithaca during the summers of 1938 and 1939 and given heavy shade with several layers of cheesecloth to reduce the light intensity to 500 foot candles maximum during the period of natural bud formation produced good vegetative growth but failed to flower or flowered very sparingly. Those plants not shaded flowered normally.

Plants prevented from flowering by giving high temperature and low light intensity failed to flower during the winter months even though the temperature was corrected. This was probably because the intensity of light during December and January was too low for flower bud formation.

It is evident from these experiments that temperatures above 65 degrees may not prevent bud formation of these plants if the light intensity is sufficient and the photoperiod correct. Low light intensity with the correct photoperiod and temperature failed to produce flowers.

Work with chrysanthemum and buddleia shows a similar response.

Probably light intensity is influencing the response of many plants to photoperiod and temperature. Most of the temperature work has been carried out under conditions of poor light intensity in winter while much of the photoperiodic work has been carried out only under one condition of light intensity, that is, either during summer when the

light intensity is great, or in winter when the intensity is low. Few plants have been treated under both conditions.

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The Growth Cycle and the Effect of Planting Stock Size on the Production of Marketable Bulbs and Flowers of Paperwhite Narcissus

By R. D. Dickey, *University of Florida, Gainesville, Fla.*

Abstract

This material will be published as a bulletin of the Florida Agricultural Experiment Station.

DATA presented relative to growth cycle show that slabs, round bulbs and mother bulbs produced round bulbs and mother bulbs and the per cent of each type which did this varied with the size. The number of double-nosed bulbs produced was very small, considerably below that indicated by the literature on the subject.

The effect of size of original planting stock upon the subsequent production of marketable bulbs was studied. It was found that the larger sizes yielded a greater number of salable bulbs over the duration of the experiment. The desirability of discarding all categories of 8 centimeters and below by commercial growers is suggested.

Experimental evidence is presented which shows that both bulb size and category have a marked effect upon flower production.

The Effect of Short Days upon the Development of the Fall Blooming Chrysanthemums

By E. P. Hume, *Cornell University, Ithaca, N. Y.*

LEAF-BUD cuttings have been used to some extent as a means for rapid propagation of chrysanthemums from limited stock. In order to apply this method as soon as flowered to the propagation of seedlings or sports, this study was made to determine the action of "short days" upon the formation and development of flower buds.

Methods

The variety Dorothy Turner was grown under normal day length conditions in the greenhouses of the Department of Floriculture at Cornell University, Ithaca, New York. At this latitude the commercial varieties have been found to initiate flower buds between the 15th and 25th of August (5).

The effect of "short days" on reproduction was determined from time to time by taking stems from these plants at 5-day intervals. Starting on August 4th and continuing through the period of bud development until the flowers had opened. During this period the day length naturally shortened from about 15 hours to 13 hours. From these stems leaf-bud cuttings were taken at regular distances along their entire length. These consisted of a leaf and a small piece of the adjacent stem including the axillary bud.

The cuttings were rooted in flats of sand. In addition to the normal day length, light of 4 hours duration and a minimum intensity of 5 foot candles was given to insure long days. The long days were continued by again placing the plants when potted under the additional light. Thus we have plants growing to various stages of flower bud development under natural day length conditions. Leaves, with their buds and surrounding tissue, were taken at regular intervals from the entire length of stem. These were propagated and grown under day lengths too long for flower bud initiation.

The next year using the variety Copper City all cuttings were made at the same time on October 30. They were taken from plants which had been given the usual commercial darkening treatment (4) starting on July 30 and August 10, as well as from normal season. The plants which were darkened ahead of normal season had progressed further in the process of reproduction at the time the cuttings were taken than had any plants the previous year. This made possible an extension of this study to cover the period of full bloom and senescence. Mallet cuttings were used in place of leaf-bud cuttings. These mallet cuttings differ from leaf-bud cuttings in that the stem is cut through above and below each cutting. The entire section is placed in the sand while in the leaf-bud method only the bud and adjacent tissue is cut out. Otherwise, the procedure was similar to the previous year. All cuttings were rooted and grown at a night temperature of 65 degrees F.

Results

The first year's results are illustrated in Fig. 1. The first visible flower bud developed from the terminal cutting from the stem taken September 17th. As the period of exposure to "short days" was extended, flower buds appeared on all shoots arising from axillary buds in the upper half of the stem. No flowers occurred in the shoots from leaf buds taken from the lower half of the stem during any stage of development.

The first flower buds to form were of the type known as "crown

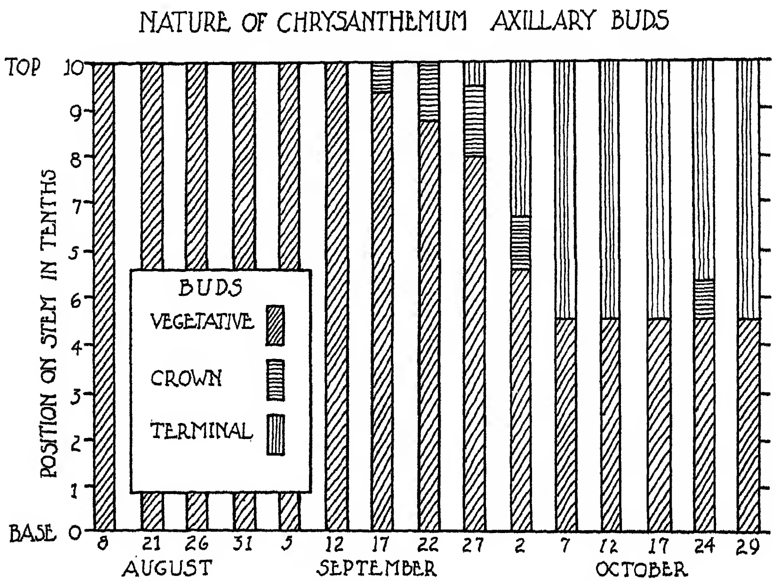

Fig. 1. Nature of chrysanthemum axillary buds.

buds". These consist of a single flower bud with leaves or bracts below. One or two weeks longer exposure to "short days" resulted in the formation of terminal buds which consist of a cluster of flower buds rather than a single bud. Only one cutting produced a crown bud after terminal buds were established throughout the upper half of the stem. This occurred from a bud just above the mid point of the stem propagated October 24th.

Side shoots which occasionally formed on shoots developing from leaf bud cuttings were always vegetative.

The results of the second experiment showed again that the buds in the lower half of the stem developed vegetative shoots when propagated and grown under long day conditions from mallet cuttings. The stems from the earlier darkened plots had become very hard and sufficient cuttings died to make the demarkation between vegetative and reproductive portions of the stem less distinct than in the previous experiment.

The first flower buds appeared on a cutting from shoots which had already received at least 20 "short days" (August 25th to beyond September 12th). During this time flower buds have developed considerably in the growing points of normal season plants. Cuttings from the upperhalf of the stem which had been exposed to longer periods of "short days" had flower buds already visible at the time of propagation. They showed practically no further increase in size when growing under long days.

Discussion

Several workers (1, 2, 3) have shown that there is produced a diffusable substance or substances in the leaves under conditions favoring reproduction. This is then transferred to the growing points and there causes the formation and development of reproductive organs. This reaction fits the generally accepted concept of a hormone. The results of this investigation showed something more of this mode of action.

Apical dominance affected its movement first to the terminal growing point and later gradually to the lateral buds in the upper half of the stem.

There are two indications that this reaction is quantitative not only in formation, but also in development of flower buds. First of all, the flower buds first formed were crown buds. Further exposure to "short days" caused the formation of terminal buds which represents a greater degree of differentiation of reproductive tissue. Secondly, flower buds develop only slightly after propagation by leaf-bud cuttings. This appears to represent a different type of mechanism from that in some other plants (1, 3) where a short induction period is sufficient to form and develop flower buds on new tissue.

In the further development of the vegetative cuttings, dormancy difficulties occurred which require additional investigations before this method is practical for propagation.

Summary

It has been shown that under the conditions of this experiment at least 20 "short days" were required before flower buds develop on any cutting propagated and grown under long days. The first bud formed on the terminal cutting. As a result of exposure to 20 "short days", axillary buds were changed progressively down the stem so that flower buds occurred on the shoots developing from these buds under long days until the midpoint of the stem is reached. No such change occurred in the lower half of the stem. At any position on the upper portion of the stem the first type of flower bud formed is the crown bud. It required 5 to 10 days more exposure to reproductive day length to effect the formation of terminal buds at the same position. Very little additional reproductive development occurred after the cuttings were made and subjected to "long days".

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The Growth of Snapdragons, Stocks and Cinerarias on Some Iowa Soils[1]

By E. C. Volz, *Iowa State College, Ames, Ia.*, and
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AT PRESENT there is little data on the growth of greenhouse flowers on different soil types. In floricultural literature, soil recommendations for specific crops are frequently given. Wiggin (3), for example, writes that carnations seem to do best on a medium loam with an abundance of humus and that he believes that carnations prefer a porous or open soil. He carefully adds in connection with these statements, however, that there are no figures available to support them. Laurie and Poesch (2) likewise state that, "A strong sandy loam of porous structure and with a good organic matter content provides the most satisfactory soil for carnations," but then go on to say, "However experimental data have shown that the plants may be grown successfully in gravel or cinders without any organic matter but with sufficient nutritive additions." Such recommendations can be found for all of the major crops.

Iowa florists, anxious to learn if soil type markedly influences growth of flower crops under glass, requested the undertaking of a project to study the response of greenhouse crops to various soils of their state. Reported herein are data on the growth of three species of greenhouse crops on some Iowa soils of definitely different origin and types.

Materials and Methods

The soils of Iowa can conveniently be classified into three groups on the basis of the conditions attendant upon their development; *viz.*, prairie soils, forest or podzol soils, and alluvial soils. Two soils were selected from each group as follows: Prairie soils—Clarion loam, Webster loam; Forest or gray-brown podzol soils—Clinton silt loam and Knox silt loam; Alluvial soils—O'Neill loam, Wabash silty clay loam.

A greenhouse compost, prepared by piling alternate layers of a Webster loam sod and manure in the ratio of 3:1 and left to decompose for a year, was also included.

Preparatory to planting, the soils were thoroughly mixed with fertilizers at the following rates: Ammonium sulfate—200 pounds per acre; Muriate of potash—300 pounds per acre; and Superphosphate 20 per cent—750 pounds per acre. All of the soils were weighed and moisture determinations made. Two million pounds dry weight, were considered equivalent to the acre furrow slice. For supplementary fertilization during the growing periods, ammonium sulfate was applied in solution at the rates given under the discussions of the specific crops. These rates were based on crop response and on soil nitrate tests using the phenoldisulphonic acid method (1).

[1]Journal Paper No. J-861 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 675.

Snapdragons (*Antirrhinum majus*), Stocks (*Matthiola incana*) and Cinerarias (*Cineraria cruenta*) were the crops tested.

Results

Snapdragons:—Seed of snapdragon, variety Cheviot Maid Supreme, was sown on August 5. The seedlings were benched into the several soils from 2-inch pots on September 20 at a distance of 8 by 9 inches. To allow for a proper analysis of the data, the soil plots were arranged in randomized blocks with three replications. Each plot was 2½ by 4 feet, with 18 plants per plot. In December and February slight nitrogen deficiency symptoms appeared and on the basis of soil nitrate tests, ammonium sulfate was added in such quantity as to raise the soil nitrates to 50 parts per million.

Individual plant records were kept on the number of flower spikes and on stem length. Only one crop was removed. Table I gives the average number of flower stems per plant and the average stem length on the several soils. Analysis of the data indicated that the average number of stems did not differ significantly when the plants were grown on these soils. The range of means of stem length is 6.2 inches, a highly significant difference which may be important in a high class flower market where the longer stemmed flowers command a higher price.

TABLE I—Snapdragons—Average Number of Flower Stems per Plant and Average Stem Length (Inches)

Soil	No. Flowers Per Plant	Mean Stem Length (Inches)
Wabash	3.70	35.9
Knox	3.96	34.9
O'Neill	4.07	33.8
Clarion	3.94	32.2
Webster	3.70	31.1
Clinton	3.69	30.3
Compost	3.93	29.7

Least mean difference for significance:	No. Flowers	Stem Length
.05	1.63	3.03
.01	2.29	4.25

Stocks:—Seed of column or non-branching stock, variety Lilac Lavender, was sown on February 26, seedlings were potted into 2-inch pots on March 16, and the plants benched April 5 at a distance of 6 by 6 inches. There were 35 plants per plot. The crop of stocks was grown in the same bench and soil that had been used for snapdragons after they were removed on the last of March when the entire first crop had been cut. Just prior to planting the stocks, fertilizers were worked into the soils at the following rate: Ammonium sulfate —200 pounds per acre; Muriate of potash—150 pounds per acre; and Superphosphate 20 per cent—375 pounds per acre.

On the basis of soil nitrate tests, made every 10 days, it was determined that nitrates were limiting on the O'Neill, Knox and Wabash soils on May 4 and on the Clarion, Clinton and Webster soils May 14, and consequently ammonium sulfate was added on those dates at the same rate as given above (200 pounds per acre).

TABLE II—STOCKS—AVERAGE HEIGHT OF PLANTS (INCHES)

Soil	Mean Height (Inches)
Knox	26.1
Compost	25.3
O'Neill	25.2
Clarion	25.0
Webster	24.2
Wabash	24.1
Clinton	24.1

Flower spikes were considered ready for cutting when 10 individual flowers were fully open. The total height of each plant was measured from the ground. Data on the height of the stock plants at harvesting are summarized in Table II. Analysis of variance indicated that the differences in the heights of these plants were probably not significant. The plants on all soils bloomed at the same time and were all of good commercial quality.

Cineraria:—Cineraria seed, variety Cremer's Prize, was sown on September 8 and the seedlings were potted in 2½-inch pots 1 month later. November 21 the seedlings were selected for uniformity and divided into 15 groups of seven and were shifted into 4-inch pots using the various soils. On the bench they were placed in randomized blocks of seven. Every block contained one pot of each soil. To reduce positional effects the blocks were rotated fortnightly.

On December 25 the plants were shifted to 5½-inch pots in which they were finished. Growth was rapid following the last shift and mid-January supplementary nitrogen fertilization was started. Each pot was given 150 cubic centimeters of ammonium sulfate solution (1 pound per 30 gallons of water) at 10-day intervals during the next 2 months.

Once a week as the plants came into bloom all that had reached a commercially salable condition were removed and judged independently by three judges on the basis of a modified score card. After judging, all of the above ground parts of the plants were removed, oven-dried, and the weight of each determined.

The average scores and dry weights of the cinerarias on the different soils are presented in Table III. Regardless of which index of performance, score or dry weight, is used, the soils line up in essentially the same order. The analyses of variance indicated that there were real

TABLE III—CINERARIAS—AVERAGE SCORE AND DRY WEIGHT (GRAMS)

Soil	Average Score	Average Dry Weight (Grams)
Compost	84.2	35.6
Webster	80.9	26.9
O'Neill	79.9	26.8
Clarion	79.7	27.8
Knox	79.3	27.8
Wabash	75.1	21.3
Clinton	74.7	19.8
Least mean difference for significance:	Score	Dry Weight
.05	3.82	3.46
.01	5.06	4.59

and highly significant differences among the score and dry weight means for the soils. These differences were without question of sufficient magnitude to be of commercial importance.

Conclusions

Snapdragons showed highly significant differences among their mean stem lengths when the plants were grown on seven different soils. Commercially the differences may not be of importance. The number of flower spikes per plant did not appear to be influenced by soil.

Stocks grew uniformly and well on all soils. Differences in plant height were not significant.

Cinerarias in pots showed differences in their response to the several soils; however, the differences between all soils were not significant. Plants on compost were far superior to those on any other soil.

The fact that many of the soils performed so nearly alike with the cinerarias, that the differences among the snapdragons were probably not commercially important, and that all of the stocks were of good quality, lead to the assumption that many soils with proper handling can be made to produce good flower crops.

Chrysanthemums and carnations are now being grown on the same soils to get information on those crops.

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Nutritional Symptoms in the Carnation[1]

By ROGER CLAPP and GAYLAND E. FOLLEY, *University of Maine, Orono, Me.*

BIEKART and Connors (1) through the triangle system of nutrient study developed a nutrient solution for carnations in sand culture. They obtained the best result with a medium of coarse sand.

Post (8) reports that when potassium was a limiting factor, the splitting was increased, but that when both potassium and phosphorus were absent a decrease in splitting resulted. He further states that in soil plots a high nitrogen soil condition increases production and at the same time increases the number of splits. On the other hand a higher potassium concentration decreased the production and reduced the number of splits. He further reports that phosphorus had no effect upon the production, but it did increase the number of splits.

Weinard and Lehenbauer (12) found no consistent relationship between the fertilizer treatment and the occurrence of split calyxes. They further report that acid phosphate, used at the rate of 40 pounds per 100 square feet, gave a 6 per cent increase in production. Steamed bone gave no increase in yield.

The New Jersey station reported (14) that the use of superphosphate in the sand had no effect upon growth or upon the pH of the medium.

Biekart and Connors (1) report that with an excess of potash, the carnation flower failed to open properly, the petals appearing as though glued together.

Poesch reports (7) that the carnation plant does not require a large quantity of plant nutrients. He further states that this crop does require a high calcium content.

Early work done in New Hampshire by Lumsden (5) in relation to commercial fertilizers shows that bone meal gave the best results as an all-around fertilizer, with Clay's fertilizer second best and hen manure third. Nitrate of soda appeared to be the least valuable, although a response was noted soon after the application was applied.

Dorner, Muncie, and Nehrling (3) reporting two years later on the use of commercial fertilizers, found that nitrogenous fertilizers produced a consistent increase in production and that nitrogen may be regarded as the limiting element in growth.

Wiggin (13) reports that nitrogen applied during bright weather of spring and fall seemed to be the limiting element for good carnation growing. Superphosphate and humus seemed limiting at all times. Wiggin further reports that there is no correlation between length of stem and size of blossom.

Pember and Adams (6) report that when nitrogen is added in large amounts the number of split calyxes of grade one and grade two flowers was reduced even when added to the extent that the plants were depressed in their growth and gave a reduction in number of

[1]This is part of the junior author's thesis for a degree of M.S. in Horticulture, University of Maine, 1938.

flowers. The authors state that a fertilizer of the analysis 4–10–4, or thereabouts, would be beneficial if applied at the rate of 5 pounds per 100 square feet. The actual nutritional needs of a carnation are probably supplied when the dry material contains 2 per cent nitrogen, 0.5 per cent phosphoric acid, and 1.5 to 2 per cent potassium oxide.

Laurie and Chadwick (4) report that when either phosphorus or potassium are deficient, the effects are similar. The plants have limber stems with foliage turning brown and dying. Deficient calcium gave weak stems.

Davis (2) reports that the carnation plant does not express as pronounced symptoms of malnutrition as does the chrysanthemum. He states that it will stand a lot of abuse but still continue to function.

Szendel (10) found that by increasing the frequency of nutrient application to sand cultures that the percentage of splits was increased. He finds some indication that phosphorus plays an important role in splitting.

Materials and Methods

Field grown plants of carnation, Peter Fisher (light pink), were received in early November, 1937. The soil was carefully washed from the roots of each plant and they were planted in a fine, washed, white quartz sand in 1-gallon glazed culture jars, one plant per jar. These jars[2] were made with a drainage hole on one side near the bottom. Glass wool was placed over this hole to prevent the sand from washing out as the culture solution drained through.

One liter a day of nutrient solution was passed through the sand by the constant drip method of Shive and Stahl (9).

The jars were placed four abreast across the greenhouse bench. Two jars receiving similar nutrient solution were placed side by side (so as to lessen work in filling solution jars), and these groups scattered at random over the area. They were further adjusted so that no two groups receiving similar treatment were adjacent. Four jars received the same excess or deficient solution and eight jars received complete nutrient solution.

The experiment was set up on the south bench in the carnation house of the University range. The house runs approximately east and west. This bench was chosen so as to afford sufficient sun at all available times, thus minimizing the possibility of shading from the regular benched carnation crop which had attained considerable height when the experiment was started.

The carnations were grown at 50 degrees F night temperature and a buoyant, airy condition was maintained in the greenhouse. The plants received fumigation for aphids along with the benched crop. Red spider mites were controlled by spraying with Selocide.

Nutrient Solution:[3]— The complete nutrient solution, patterned after that proposed by Biekart and Connors (1) for carnations in sand culture, consisted of:

[2]Product of Red Wing Pottery Co., Red Wing, Minn.

[3]Baker's C.P. reagents were used.

	Grams per Liter
Ammonium sulphate, $(NH_4)_2SO_4$............	0.1835
Potassium phosphate monobasic, KH_2PO_4......	0.2836
Magnesium sulphate, $MgSO_4.7H_2O$...........	0.5822
Calcium nitrate, $Ca(NO_3)_2.4H_2O$............	2.407

Minor elements were added as follows: iron 1 part per million, manganese 1 part per million and boron 0.5 part per million.

To create deficiencies of the several elements, substitute salts were used as follows:

Minus N, Na_2SO_4 was substituted for $(NH_4)_2SO_4$ and $CaCL_2.2H_2O$ was substituted for $Ca(NO_3)_2.4H_2O$
Minus P, KCl was substituted for KH_2PO_4
Minus K, $NaH_2PO_4.H_2O$ was substituted for KH_2PO_4
Minus Ca, $NaNO_3$ was substituted for $Ca(NO_3)_2.4H_2O$

Where an excess of the element was used, the salt containing it was doubled in amount. In the case of nitrogen the excess was divided between the two nitrogen carriers, ammonium sulfate and calcium nitrate, each contributing one and one-half times the regular amount.

The concentrations of the solution were checked by the freezing-point depression method. The cryoscope readings were: complete solution, 0.9026; +N, 1.149; —N, 0.6111; +P, 0.9882, —P, 0.9849; +K, 1.065, —K, 1.069; +Ca, 1.456; —Ca, 0.8249 atmospheres. There is some variation among the solutions but it is believed that the discrepancies were not of sufficient magnitude to warrant any changes in the nutrient solutions.

The hydrogen-ion concentrations of media and solutions, presented in Table I, show that both were strongly acid and that the media had a reaction less acid than that of the solution dripping into it.

Results

Excess Nitrogen:—Healthy, vigorous plants developed when the amount of nitrogen was doubled. Those receiving an excess of nitrogen had as stout stems and as large flowers as the plants grown on the complete nutrient solution but the stems and internodes were shorter. They exhibited a higher percentage of splits.

Deficient Nitrogen:—The plants with deficient nitrogen were stunted, the growth was hardened and the leaves were narrow with margins which were curled upward and inward. The tips of the older leaves exhibited a slight yellowing followed by complete yellowing. The blooms were smaller than those of the control, and the percentage of splits markedly decreased. The stems were slender and shorter.

Excess Phosphorus:—The cultures with excess phosphorus resembled those of the control somewhat but were much smaller and lacked the characteristic healthy leaves. There was such variation in stem strength that it appeared unwise, if not impossible, to express it as a characteristic symptom. Two "bullheads"[4] were produced from the cultures during the course of the experiment. The blossom size

[4]Flower exhibiting an overabundance of petals.

TABLE I—Hydrogen-ion Concentration

	Complete	+N	−N	+P	−P	+K	−K	+Ca	−Ca
Solution	5.3	5.2	5.3	5.0	6.6	5.2	5.3	5.2	5.3
Media*	5.5	5.6	5.6	5.5	5.8	5.5	5.6	5.7	5.6

*Fine, white quartz sand.

was smaller than in the control, whereas the average length of internode was equal to that of the control. In addition, the average stem length was smaller, but not as small as those of the cultures deficient in nitrogen. The percentage of splits was high.

Deficient Phosphorus:—Plants lacking in phosphorus did not make much new growth, but what they did make was slender. The plants tended to be stunted, producing a hardened growth. The leaves did not exhibit the vigor which was characteristic of the control. Slender stems, a slight decrease in splits, a considerable decrease in size of bloom and average length of internode, and only a slight decrease in total stem length resulted from the treatment.

Excess Potassium:—Plants in the presence of an excess of potassium made very little growth. Most of the leaves were small and none approached the maximum size found in the controls. The percentage of splits was high with the average blossom size showing a considerable decrease from the controls. The average length of internode and average stem length was the smallest of any in the whole experiment. The stems were slender, and one "bullhead" was produced. There was a resemblence between these cultures and those with a deficiency of nitrogen. The leaves failed to show symptoms of malnutrition other than that they were narrow and lacked the healthy bloom of the control.

Deficient Potassium:—Deficient- potassium plants exhibited a decidedly stunted growth with slender hard stems. The percentage of splits was increased somewhat, whereas size of bloom was exceedingly small. The stems had decreased internodes, as well as, decreased total length. The leaves were narrow and lacked the healthy bloom which was characteristic of the control. These plants exhibited even less growth than did those lacking phosphorus.

Szendel (11) reported to this group last year that in the advance stages of potassium deficiency, after 6 months of the deficiency, small yellowish, necrotic spots developed on the young leaves and on those from the middle part of the plant.

Excess Calcium:—Excess-calcium plants exhibited vigorous and healthy growth equal to the control. The stems were stout, and the percentage of splits was the same as the complete nutrient solution, but the average size of bloom was a little smaller. The length of internode and the length of stem was slightly smaller than the plants on complete solution.

Deficient Calcium:—Deficient-calcium plants died within a period of 9 weeks after calcium was omitted from the nutrient solution. The plants turned pale green and then died. Not enough bloom was produced to attach any significance to them. They produced slender stems with small internodes and short stems.

The measurements of the flowers produced by the various cultures are summarized in Table II.

TABLE II—Flower Production by the Plants Receiving the Excess or Deficient Solutions

Culture	Total Blooms†	Number Split	Per Cent Split	Average			
				Blossom Size (Cm)	Internode Length (Cm)	Stem Length (Cm)	Stem Strength
Complete	21*	7	33.33	6.80	5.74	29.92	Stout
+N	7	3	42.86	6.77	5.24	23.10	Stout
−N	11	2	18.18	6.25	4.51	24.43	Slender
+P	10	5	50.00	6.43	5.76	25.11	S, M, and S
−P	10	3	30.00	6.34	5.35	27.20	Slender
+K	10	5	50.00	6.36	3.58	18.02	Slender
−K	9	4	44.44	6.15	4.25	22.24	Slender
+Ca	9	3	33.33	6.33	5.52	27.07	Stout
−Ca	2	1	50.00	4.25	4.71	23.55	Slender

*Eight cultures.
†Benched November, concluded May 1.

Summary

When the solutions either contained an excess or were deficient in nitrogen, phosphorus, potassium or calcium there were no clearly defined symptoms except with the plants deficient in nitrogen which did exhibit a yellowing of the leaves. The best looking plants were those receiving the complete, excess-calcium and excess-nitrogen solutions. All others produced blooms of an inferior quality and in no instance did the plants appear as healthy.

Plants receiving a deficiency of nitrogen are stunted and promptly become yellow. Those receiving an excess of potassium are likewise stunted and ultimately become yellow at the tips only.

With the exception of those deficient in nitrogen or in phosphorus, and those with an excess of calcium, all others produced a higher percentage of splits than the controls. Excess calcium, excess nitrogen, and the complete solution were the only treatments which produced stout stems.

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Seed Treatments with Phytohormones and Talc[1]

By J. A. DeFrance, *Rhode Island Agricultural Experiment Station, Kingston, R. I.*

THE comparatively recent use of synthetic growth promoting substances in vegetative propagation and other horticultural practices to produce various plant responses has led to its consideration for treatment of grass seed to stimulate germination, increase top and root growth, produce denser turf and increase disease resistance.

Grace (2) using the method of seed treatment developed in his laboratory whereby application of hormone-chemicals is made with the use of a dust carrier, obtained stimulation of both root and top growth of barley seedlings grown in sand, and increased the dry weight of the tops and roots of month-old wheat plants grown in soil. He also tested a number of varieties of garden seeds and similar response was shown. He states, "whether the increased early growth so clearly demonstrated in the laboratory and greenhouse can be translated to increased yield of crops in the field, can be demonstrated only by field experiments".

Stier and du Buy (3) treated tomato seeds with certain phytohormone-talc preparations and obtained increased percentages of germination. The subsequent treatment of the plants with solutions of either indolebutyric or naphthaleneacetic acid at transplanting resulted in: (a) acceleration of the time of flowering; and (b) production of greater yields of fruit.

Youden (4) treated wheat and soybean seeds in the dry state with indoleacetic acid, naphthaleneacetic acid, indolebutyric acid, talc, and Rootone to determine whether they influenced seed germination and seedling growth when grown in sand and soil in the greenhouse and in the field. No significant case was found in which the germination and growth of the treated lots exceeded the controls and in many cases the controls were superior to the treated lots.

From the results of tests in which stolons, seed, and turf of various grasses were treated with numerous preparations of different types of growth substances, Cornman and Bengtson (1) state that, "there appears to be little or no likelihood of helping grass in a practical way with any of the growth substances now available".

A field test was made on a portion of the Rhode Island Agricultural Experiment Station farm at Kingston to determine the effect of various phytohormone dusts, commercial preparations, and talcs on germination, growth, development and disease resistance of Rhode Island bent (*Agrostis tenuis* Sibth.) and Kentucky bluegrass (*Poa pratensis* L.).

Materials and Methods

The following phytohormone dusts and materials were used: Auxan 1, Auxan 2, naphthaleneacetic acid, a mixture of naphthaleneacetic acid and thiourea; P.C.C. Talc, obtained from the Pennsylvania Chemical Corporation, Orange, New Jersey; Rootone, and A.C.P. Talc

[1]Contribution No. 591 of the Rhode Island Agricultural Experiment Station.

from the American Chemical Paint Company, Ambler, Pennsylvania; and Hormodin No. 1 and Merck Talc from Merck & Co., Rahway, New Jersey. These materials were applied at the rate of one ounce to 10 pounds of grass seed and thoroughly mixed with the seed before planting. Thus, the seed was treated with the various phytohormone-talc mixtures; and also with the various talcs alone that were used as carriers of the phytohormones, and was planted on fertilized and unfertilized plats. Rhode Island bent was seeded at the rate of 2½ pounds, and Kentucky bluegrass at 5 pounds to 1,000 square feet. The area planted to each grass was 50 by 30 feet, consisting of 60 plats, containing 25 square feet each. All treatments and control plats were in triplicate.

A 4–12–4 fertilizer made up of sulphate of ammonia, superphosphate, and muriate of potash was thoroughly mixed with the upper 3 inches of soil at the rate of 20 pounds to 1,000 square feet before seeding the fertilized plats. The soil (pH 5.0) was prepared in May; fertilizer was raked into the soil of certain plats June 4, and all plats were seeded individually on June 5.

An average of five readings of height of grass was made on each plat prior to mowing periods. Four sets of measurements on top growth were made during the season. Root samples were taken as 1-inch plugs to a depth of 10 inches. Nine borings of each treatment were made in August and also in September. These were placed on wire screen and washed free of soil.

Density was measured the last of August and refers to the amount of crowding together of the leaves.

Large Brownpatch disease, caused by *Rhizoctonia solani* Kühn, which is quite severe on Rhode Island bent under conditions of high humidity and high night temperatures, was recorded in early August after an infestation. This was the heaviest attack during the season and afforded an excellent opportunity to observe the effects of the phytohormone treated lots with regard to disease resistance.

Results and Discussion

The effect of the various phytohormones and their respective talc-carriers on germination, rate of top growth, density of turf, and disease resistance is shown in Table I.

Germination:—There were no noticeable differences in rate of germination and emergence of the seed with regard to the various phytohormone or talc treatments. Five days after planting, the seed on the unfertilized plats of Rhode Island bent had germinated and seedlings were up ⅛ to ¼ inch. Kentucky bluegrass was much slower to germinate and appeared 10 days after seeding. However, where the soil had been fertilized just previous to planting, the Rhode Island Bent seed took approximately one day longer to germinate than on the check and other plats that received no preseeding fertilization. This was due apparently to the fertilizer withholding some moisture necessary for germination. This, however, was not the case with Kentucky bluegrass which did not exhibit this difference, thus uniform germination was noted on the entire area. The few days difference in the normal rate

TABLE I—PHYTOHORMONE AND TALC TREATMENTS OF RHODE ISLAND BENT AND KENTUCKY BLUEGRASS SEED

Treatment	Rhode Island Bent				Kentucky Bluegrass		
	Germination† (Days)	Height** (Inches)	Density (Per Cent)	Brown‡ Patch (Per Cent)	Germination (Days)	Height (Inches)	Density (Per Cent)
Rootone	5	1.12	62	3.4	10	1.05	36
Rootone*	6	1.91	86	2.6	10	1.79	53
A. C. P. talc	5	1.13	62	2.8	10	1.03	35
A. C. P. talc*	6	1.90	90	1.1	10	1.70	52
Hormodin No. 1	5	1.21	62	2.7	10	.97	32
Hormodin No. 1*	6	1.91	90	1.4	10	1.82	59
Merck talc	5	1.19	66	2.0	10	1.09	38
Merck talc*	6	2.03	88	1.5	10	1.61	52
Auxan No. 1	5	1.34	68	1.9	10	1.18	44
Auxan No. 1*	6	1.92	91	2.4	10	1.69	59
Auxan No. 2	5	1.17	62	2.6	10	1.07	39
Auxan No. 2*	6	2.01	88	1.5	10	1.76	55
P. C. C. talc	5	1.22	64	1.8	10	.99	38
P. C. C. talc*	6	1.92	92	1.8	10	1.71	54
Naphthalene acetic acid	5	1.20	68	1.6	10	1.04	39
Naphthalene acetic acid*	6	2.00	96	3.0	10	1.78	57
Naphthalene acetic acid and thio-urea	5	1.28	68	2.1	10	1.03	54
Naphthalene acetic acid and thio-urea*	6	2.02	91	1.8	10	1.79	56
Check	5	1.29	66	2.3	10	1.08	40
Check*	6	2.04	88	2.9	10	1.68	57

* = With preseeding fertilizer 4–12–4 at 20 pounds per 1,000 square feet.
** = Average of heights measured before each mowing during the season. Sixty readings of each treatment.
† = Grass germinated and up about ⅛ inch.
‡ = Notes on Brownpatch taken after attack of disease on August 13.

of germination of Kentucky bluegrass undoubtedly allowed the fertilizer time to go into solution and not interfere with germination.

Top Growth:—The data in Table I show no significant differences in the average rate of top growth of Rhode Island bent between the different phytohormone treatments, and the controls, nor between the various materials and their respective talc carriers. The main difference that can be noted is the response on the plats that received the preseeding fertilizer whether or not the seed was treated with phytohormone. The results were much the same with the Kentucky bluegrass series. No significant differences that could be attributed to the treatments were noted with regard to the rate of top growth on the fertilized or unfertilized plats.

Density of the Turf:—No significant increases in density were noted on the unfertilized plats of Rhode Island bent; however, there appeared to be a slight increase on the lot treated with naphthaleneacetic acid on the fertilized plats. The treated plats of Kentucky bluegrass had much the same density as the controls, except in the case of naphthaleneacetic acid dust and thiourea on the unfertilized plats which had a percentage rating of 54 as compared with 40 for the check. In a few instances the treated lots were not so dense as the control plats.

Root Growth:—No differences were noted in length or amount of roots on any of the plats planted with hormone-treated seed.

Large Brownpatch disease apparently was not controlled or reduced appreciably by the phytohormone seed treatments either on the fertilized or unfertilized plats.

In all cases the use of preseeding fertilizer produced an increase in top growth and density on both the Rhode Island bent and Kentucky bluegrass plats. The rate of germination, growth and density of the bent grass was superior to bluegrass.

Summary and Conclusions

A field study was made to determine the effect of seed treatments with certain phytohormones and talc on germination, growth, density, and disease resistance of Rhode Island bent and Kentucky bluegrass; with and without preseeding fertilization. No increase in rate of germination of the treated seeds was noticeable on either the fertilized or unfertilized plats. In no case did the top growth of the treated lots exceed the controls on either the fertilized or unfertilized plats of Rhode Island bent and no significant differences occurred on the Kentucky bluegrass series with regard to top growth.

There was no consistent increase in density with any of the treatments and in certain cases the treated lots were not so dense as the controls. No differences were noted in length or amount of roots on any of the treated lots when compared with the controls. There was no substantial evidence that large Brownpatch disease was controlled by the various treatments. There was a decided increase in top growth and density on both the treated and untreated lots where preseeding fertilizer was used. Observations of these test plats will be continued during the season of 1941 to ascertain any further results.

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Studies With Rooting Media for Florida Ornamentals

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IT IS well known that a congenial medium is of first importance in the successful rooting of cuttings. Some of the essential characteristics of such a medium are—the ability to hold large amounts of water, the capacity for aeration as occasioned by a porous, friable condition, freedom from toxic substances and a slightly acid reaction for most of the ornamental plants that are grown by Florida nurseries. In addition, the substance must be free from rapidly decaying material and it must be comparatively cheap and easily accessible.

In order that recommendations could be made to Florida nurserymen, trials were conducted with leafy softwood cuttings during the spring and summer of 1939. The investigations were conducted on the grounds of the Horticulture Department of the Florida Agricultural Experiment Station and cuttings were taken from plants in the collection of the University of Florida.

The most widely used rooting medium is sharp sand, but it is not necessarily the best for Florida ornamentals as shown by data presented herewith. Apparently the addition of a suitable organic material to the sharp sand makes for a more congenial mixture for cuttings to stand in while their roots are being formed. Ordinarily, the natural organic soils of Florida are heavily infected with decay organisms and, without sterilization, they are unsuitable for rooting media.

For the tests reported here, several organic and inorganic materials, some of them by-products of southern crops, were used in varying combinations. Each substance, in mixture, produced a medium that was loose in texture, open, friable and very agreeable to handle.

A temperature that is favorable to the normal, active growth of a mature plant is necessary for the rooting of its tips as cuttings. That the temperatures during these investigations were most favorable is attested by the facts that root formation was rapid, mortality was low.

Materials and Methods

A ground bed was constructed in a standard half-shade lath house by placing 8-inch planks of pecky cypress on edge. At 3-foot intervals, cross partitions were installed and into these resulting sections, the different media were packed. Light bamboo frames, to which double layers of cheesecloth had been fastened, were employed to diffuse the sunlight and to protect the leafy cuttings from drying winds. These frames were lifted each day at noon and the plant material was thoroughly syringed with a fine spray. During the months of May through September, this equipment has given satisfying results with more than 70,000 cuttings and apparently such facilities are adequate for summer propagation of leafy cuttings in Florida.

The media that were used in these studies are briefly described as follows: *Peat moss*—the horticultural grade of the baled European

product. *Peanut hulls*—ground peanut shells that had been received from a large peanut processing plant. *Pecan hulls*—crushed shells that are now waste material at pecan cracking plants. *Sawdust*—fresh, undecayed cypress sawdust that was delivered from a local mill. *Mikolite* —the trade name for a vermiculite ore from Wyoming that has been expanded at about 2,000 degrees F. This sterile silicate of iron, aluminum and magnesium, sold as a proprietary soil conditioner was furnished by the manufacturer. *Coarse quartz sand*—a yellowish-white sand pumped from Florida's fresh-water lakes is widely used in the building trades. This substance was used alone, as well as in half-and-half mixtures with peat moss, peanut hulls, pecan hulls and sawdust. *Norfolk subsand*—strictly, Norfolk fine sand, subsurface—the fine yellow sand that is procured by digging some 3 feet below the surface of the soil upon which the University of Florida stands. This material is free from organic matter, and was mixed in equal parts with peat moss as one medium in the experiment.

The operator was watchful that the cuttings remained turgid while they were being collected and prepared for the bed. The stem cuttings were made up in the usual way, about 4 inches in length with the upper two or three leaves intact. The leaf-bud cuttings were prepared after the manner described in a former paper (1). As prior tests (1, 2) showed that cuttings listed in Tables I and II developed root systems more quickly when they were treated with a root-inducing chemical, all of the cuttings in this trial were dipped in hormonized talc. As optimum concentrations had been determined in these earlier tests (1, 2), the percentage of indolebutyric acid in the talc carrier varied with the species that was being treated.

The standard cuttings were set at a slant of approximately 30 degrees so that the leaves were in close contact with the moist substratum. The shields of stem tissue in the leaf-bud cuttings were just barely covered, the single leaf lying flat on the rooting medium. After the plant material had been set, the bench was flooded with a gentle stream from the hose and the cheesecloth shades were put into place. Random selections were made for inspection every 10 days and the entire lot of any given variety was lifted for recording when 80 per cent or more of the leading group was ready for potting.

The technique described above has given good results in these and earlier propagation experiments. The cuttings remained in excellent condition in all cases; wilting and abscission of the leaves were not observed, and mortality was quite low. Representative individuals from all classes were potted for further observation. They grew into normal plants that were salable at the end of the first season.

Results

Data presented in Tables I and II indicate that several mixtures of organic and inorganic substances are acceptable as rooting media for plants that are widely grown as ornamentals in Florida. These data show significant responses of all species tried in the various mixtures. However, certain plants were outstanding for one or another reason and these might be noted.

TABLE I—RESPONSE OF STANDARD CUTTINGS* TO DIFFERENT ROOTING MEDIA

Media	pH	*Hydrangea macrophylla* (Otaksa)	*Chilopsis linearis*	*Thryallis glauca*	*Duranta repens*	*Podocarpus macrophylla maki*	*Vitex agnus-castus*	*Cocculus laurifolius*	*Azalea canescens*	*Schinus terebinthifolius*	*Severinia buxifolia*	*Ilex cornuta*	*Ficus repens*
Norfolk and peat	4.82	8	10	10	10	7	7	8	8	6	10	4	2
Peanut hulls and sand	6.29	10	10	10	6	7	9	9	7	5	5	2	6
Peat moss	3.95	10	10	9	8	9	9	5	9	4	3	6	2
Peat moss and sand	4.45	10	10	9	10	7	10	4	5	7	3	3	3
Pecan hulls and sand	5.85	10	10	8	8	9	2	7	3	8	3	8	3
Norfolk subsand	4.29	10	10	7	3	8	6	8	7	0	5	3	0
Coarse quartz sand	6.31	10	4	9	8	2	3	0	0	0	1	0	7
Cuttings ready for potting by variety	——	68	64	62	53	49	46	41	39	30	30	26	23

*Ten cuttings of each variety were dipped in a hormonized talc (2) and inserted in each medium.

Hydrangea macrophyll, Otaksa showed the greatest tolerance for rooting media, giving a very high percentage of heavily rooted cuttings in all substances. *Ilex cornuta* and *Ficus repens* were apparently least tolerant, showing a definite reluctance to root in several media.

While no significant differences are seen between responses in the mixtures, most species demonstrated a notable reluctance to root in the sands containing no organic material. There is no apparent correlation between acidity and rooting.

With leaf-bud cuttings, Croton (*Codiaeum variegatum*) showed the greatest tolerance for varying media, while single red hibiscus (*Hibiscus rosa-sinensis*) was least tolerant in this respect.

Using Chi square, the numerical difference between the response of the stem cuttings to organic mixtures and their response to washed

TABLE II—RESPONSE OF LEAF-BUD CUTTINGS* TO DIFFERENT ROOTING MEDIA

Media	pH	*Codiaeum variegatum* (maculatum katonii)	*Codiaeum variegatum* (var. tortilis)	*Codiaeum variegatum* (Baronne de Rothschild)	*Cocculus laurifolius*	*Azalea indica formosa*	*Hibiscus rosa-sinensis* (Single red)
Peat and mikolite	6.11	9	10	10	10	7	10
Peat and sand	4.45	10	10	9	9	10	7
Sawdust and sand	6.21	10	9	10	8	7	5
Norfolk subsand	4.29	10	10	8	9	6	6
Cuttings ready for potting by variety	——	39	39	37	36	30	28

*Ten cuttings of each variety were treated with a hormonized talc (2) and inserted in each medium.

sands is seen to be significant. The probability of occurrence by chance is less than one in a hundred. On the other hand, by the same method, the rooting response of the leaf-bud cuttings to organic blends in comparison to their behavior in Norfolk fine sand, subsurface, was found to be insignificant.

In terms of percentage, 70 per cent of stem cuttings, all species, from mixtures were ready for potting, while only 46 per cent of those from sand were well rooted. In the trial with leaf-bud cuttings, 88.8 per cent of those in blends were well rooted while 70 per cent of the cuttings, all species, in washed sand, were ready for potting.

Conclusions

Several different mixtures may be used for rooting cuttings of Florida ornamentals. Blends of organic substances with sand are apparently more acceptable than are washed sands. It is suggested that plantsmen who have been using washed sand exclusively for propagation by cuttage consider the use of different mixtures to increase those plants which show a resistance to multiplication.

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Peat Moss as a Soil Amendment for Roses

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THE rose is one of the more popular garden plants and the preparation of the soil under garden conditions is an important consideration. Manure has been recommended as a beneficial material to use, but in urban districts the difficulty of obtaining an adequate supply of satisfactory quality greatly limits its use. At the suggestion of the American Rose Society some experiments were started to find a satisfactory substitute for manure in the preparation of soil for garden roses.

In the spring of 1938 some experiments were started to demonstrate the relative value of different types of organic materials on the growth of roses. Imported German peat moss which was generally considered to be harmful was included with the other organic materials in order to observe its supposed deleterious effects. Almost immediately, the appearance of the plants showed the addition of peat moss to be not only unharmful, but exceedingly beneficial under the conditions of the test.

MATERIALS AND METHODS

Two-year-old field grown hybrid tea roses of the varieties Signora and Miss America budded on multiflora understocks were used. The plants were set in the early spring (about April 1st). They were pruned to about 6 inches above the ground. No other pruning treatment was given except that in each succeeding spring they were again pruned back to 6 inches above the ground.

Common readily available types of organic materials were used. The soil was removed from the beds to a depth of 18 inches. The organic material mixtures were made on a volume basis. The soil and organic materials were thoroughly mixed outside of the beds. pH determinations were made every 2 weeks throughout parts of the period of the experiment. The pH was determined by the Quinhydrone Electrode Method. Since the soil was of a naturally fertile type, no fertilizers were applied during the period of the experiment.

The soil selected was Chenango silt loam. The organic materials used were well rotted manure, imported German peat moss and cultivated reed peat (hyperhumus). The peat moss was mixed with the soil in the proportion of one part of peat to one part of soil by volume. The well rotted manure was used in the proportion of one part of manure to two parts of soil and the cultivated reed peat as one part to three of soil.

The plots were 10 by 5 feet and each was planted with 12 uniform plants of each of the two varieties.

During the growing season the flowers were removed periodically, and the number recorded. Only the flower and its pedicel was removed so that none of the shoot growth was cut off. At the end of the season the entire shoot growth of each plant was measured and recorded.

TABLE I—THE EFFECT OF DIFFERENT TYPES OF ORGANIC MATERIALS ON THE GROWTH OF THE HYBRID TEA ROSE SIGNORA

Organic Material	Mean Shoot Growth (Inches)		
	1st Season	2nd Season	3rd Season
Check soil, Chenango gravelly silt loam	32.4	89.7	128.5
Peat moss (1 part to 1 part of soil)	94.5	164.5	196.9
Cultivated reed peat (1 part to 3 of soil)	38.3	92.1	123.5
Manure (1 part to 2 of soil)	19.3	30.2*	169.0†

*Mean of eight plants; four of the 12 had died.
†Mean of three plants; nine of the original 12 had died during the course of the experiment.

RESULTS

The results of this experiment in total shoot growth over a three year period for the variety Signora are recorded in Table I. The flower production of the variety Signora and the growth and flowering response of the variety Miss America showed the same general trend.

Peat moss was the only organic material which consistently improved the growth of the roses over a 3-year period. The cultivated reed peat plots showed a slight improvement over the check but this slight difference did not prove to be statistically significant.

It is important to note that the greatest benefit in growth was observed during the first season. Statistical analysis showed odds greater than 9999 to 1 in favor of the peat moss treatment at this time. At the end of the second season the odds were only 121 to 1. By the end of the third season, even though the apparent difference between the plots was large, the odds were only 29 to 1 in favor of the peat plot, largely because of the increased variability of the plants. This substantiates the observation made in other experiments that the greatest benefit of peat moss is evident during the first season of growth.

DISCUSSION

The benefit derived from incorporating peat moss in the soil is not wholly understood. It is possible that the peat may have changed the hydrogen ion concentration to a more favorable point. This, however, is not well borne out by the pH determinations made during the course of the experiment. The pH value of the original soil as indicated by samples taken 6 inches below the surface was 6.18. With the addition of peat the pH value dropped to 5.10. At the end of 4 months the pH value of the soil plot was 6.12 while the pH value of the peat plot had raised to 5.80. During the second years growth the pH value for the soil plot varied from 6.04 to 6.37, while the peat plot varied from 5.81 to 6.2. During the third season the pH value maintained the same relationship. It seemed doubtful that this slight difference in pH value could be responsible for the decided difference observed in growth.

There is the possibility that the peat might have affected the nutrient content of the soil. Periodic tests by the Morgan Universal Soil Testing System showed the nitrate nitrogen to range between low and very-low in the peat plot but medium to medium-high in the

soil. This suggests that a low nitrate content in the growing media is more condusive to the growth of roses than a higher one.

The difference in water holding capacity of the different soil and soil-organic material mixtures varied considerably and it is possible that these differences may have exerted some effect. The peat also affected the aeration and physical condition and these factors undoubtedly played some part in improving the growth.

The plants set in the soil manure mixture seemed to be at a disadvantage from the start. Several of the plants failed to make any growth at all and died before the end of the first season. By the end of the third season more than half of the plants had died. The amount of manure used was higher than would normally have been applied under garden conditions. It is possible that if a lesser amount had been incorporated more favorable growth conditions would have been obtained. The large quantity was used to emphasize any favorable or deleterious effects from the use of manure.

It is possible that the low hydrogen ion concentration observed soon after the plants were set may have accounted to some extent for the poor growth. While the original pH value of the soil was 6.18, the pH value of the soil-manure mixture was 7.91. By the end of 4 months the pH value had lowered to 6.96. Throughout the rest of the experiment the pH value of this plot averaged about .5 pH higher than the soil.

The nitrate nitrogen content was also a possible factor. In the soil manure mixture the nitrate content by the Morgan test was very high during the early part of the first season and varied from medium-high to high during the following seasons.

The water holding capacity of the soil-manure mixture was somewhat higher than the soil alone but not as high as that of the soil peat mixture. The aeration and physical condition of the soil was not altered as greatly as when peat was used.

This paper is not presented to answer the questions concerning the value of peat moss as a soil amendment but rather to show that peat is a desirable substitute for manure in the preparation of the soil for roses. It serves also to point out some of the problems or factors involved in the preparation of the soil for roses which will form the basis for future work of a more detailed nature.

Further Studies on the Effects of Synthetic Growth Substances on Cuttings and Seeds

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THIS report, presented in brief form, is a continuation of the one given last year to this Society, and includes most of the experimental work with cuttings and seeds conducted at Ohio State University during the past year. Tables are omitted since a complete report will be published elsewhere.

Cuttings

Cuttings of Narrowleaf Evergreens:—The effects of synthetic growth substances on the rooting of various species of narrowleaf evergreens have been rather intensively investigated. Recently, various auxiliary methods of technique and treatment have been suggested to supplement the effects of these substances.

Effect of Acidity of Growth Substances on Rooting

Commercial preparations such as Rootone, Transplantone and Hormodin were thoroughly mixed with sufficient malic acid to lower the pH to 3. These mixtures, together with the regular preparations, were used to treat cuttings of *Juniperus chinensis pfitzeriana* and *Taxus cuspidata* taken at various times of the year; namely, November 30, January 7, February 7, and March 8.

The acid mixtures gave significantly better results than the regular mixtures with the November 30 cuttings of Pfitzer Juniper and the November 30 cuttings of Japanese Yew treated with Rootone 9A. Cuttings of *Juniperus chinensis pfitzeriana* taken November 30 rooted 36 per cent when treated with Rootone 9A, 64 per cent when treated with acid Rootone 9A, 64 per cent with Hormodin 3, and 80 per cent with acid Hormodin 3. Taxus cuttings taken on November 30 rooted 36 per cent with Rootone 9A, 60 per cent with acid Rootone 9A, 44 per cent with Hormodin 3, and 16 per cent with acid Hormodin 3. In all other cases the acid mixtures were more or less toxic. This may have been because the increased acidity makes the growth substance more effective, thereby causing the reaction of a stronger concentration. Cuttings taken after the first of the year, when their rest period has been broken, will not tolerate the stronger concentrations. Previous experiments have indicated the necessity of using weaker concentrations of growth substances in late winter.

The stimulating effect of Transplantone 2 on the November 30 lots of juniper and taxus was rather interesting. Nearly all unrooted cuttings of juniper treated with Transplantone were callused when removed from the bench. All except one of the unrooted cuttings of juniper treated with acid Transplantone 2 had developed root initials. These unrooted cuttings were replaced in the sand and a few weeks later nearly all of them had rooted sufficiently for potting. There was

no toxic effect of Transplantone on the cuttings. This was not true with Hormodin and Rootone.

The two plants responded differently to treatment. With the Pfitzer Juniper, the optimum treatments gave significantly better results than the controls at all times tested. With *Taxus cuspidata,* the control rooted better than any treatment with the cuttings taken January 7 and March 8. With the February 7 lot the optimum treatments gave significantly better results than the control and with the lot taken November 30 the optimum treatments were only slightly better than the controls.

Effect of Talc Alone on Rooting

Canadian talc dust alone was used in the acidity tests to check its effectiveness. With juniper the effects were inconsistent. With taxus the talc showed some positive effects on lots taken November 30 and February 7 giving some support to the contention that talc alone has some stimulating effects. With the November 30 lot of cuttings, those treated with talc rooted 88 per cent compared with 68 per cent for the controls. The results with the February 7 lot were even more significant.

The Relation of High Bottom Heat to the Effectiveness of Growth Substances

A bottom heat of 80 to 85 degrees F was compared with one of 70 to 75 degrees F in the rooting of *Juniperus chinensis pfitzeriana* and *Taxus cuspidata.* The results obtained with the high bottom heat were unfavorable. This may have been due partially to the difficulty in adequately controlling the moisture of the medium. In no case was the rooting higher where the high bottom heat was used and in three of the five tests it was significantly less.

Effect of Retreatment with Growth Substances on the Rooting of Evergreen Cuttings

After most of two lots of each of *Juniperus chinensis pfitzeriana* and *Taxus cuspidata* cuttings were callused, they were removed from the bench, retreated with the same substance that was used originally and replaced in the bench. In the few cases where roots or root initials had already appeared, a retreatment was not given since the concentrations optimum for root initiation are altogether too strong to favor root growth.

The effects of retreatment were not consistent. With the Pfitzer Juniper cuttings taken November 30, a retreatment with Rootone 9A was slightly beneficial, while the retreatment of Hormodin 3 was detrimental. With the lot taken January 7 the reverse was true. The only striking positive result was obtained in the retreatment of the November 30 lot of *Taxus cuspidata* cuttings with Hormodin 3. But in this case the controls rooted as well as the treatments. Certainly the results of this experiment do not warrant the extra labor involved although retreatment had the tendency to produce heavier root systems.

Effect of Vitamin B_1 on the Rooting of Evergreen Cuttings

A preliminary experiment was set up in order to ascertain the effect of vitamin B_1 on cuttings previously treated with synthetic growth substances. Duplicate lots of cuttings of *Taxus cuspidata* and *Juniperus chinensis pfitzeriana* were set January 7 and one lot was watered with a 1-1,000,000 solution of vitamin B_1 January 19.

The addition of vitamin B_1 had no effect except when the cuttings had been previously treated with synthetic growth substances. With previous treatment the results were significant, especially with *Taxus cuspidata.* Taxus cuttings taken in January rooted as follows: control 70 per cent, acid Rootone 9A 30 per cent, acid Hormodin 3 40 per cent, acid Rootone 9A plus vitamin B_1 80 per cent, and acid Hormodin 3 plus vitamin B_1 90 per cent. This supports the theory that vitamin B_1 does not stimulate root initiation on cuttings but does stimulate the growth of the initials after they have formed. Another significant result was that the addition of vitamin B_1 apparently rendered the acid mixtures less toxic.

Contributing Effect of Injuring the Base of the Cutting Before Treatment

Injuring the base of *Ilex opaca* cuttings before treatment with synthetic growth substances has given an additional effect in root production. Since Pfitzer Juniper is usually difficult to root in good percentages, this plant was chosen for experimentation. One lot of 25 cuttings was prepared by making two opposite slits on the lower inch of each cutting with the point of a knife. The knife was twisted slightly and then drawn down so that a slight groove resulted. This lot and a check lot of cuttings were then treated with Hormodin 3.

The effect of injury was significant, particularly in the formation of heavier root systems on the sliced cuttings. Sliced cuttings rooted 52 per cent while the unsliced cuttings rooted only 24 per cent. Forty-eight per cent of the sliced cuttings had heavy root systems while only 8 per cent of the unsliced cuttings showed heavy root systems. The percentage of rooting was not particularly good in any case but it must be remembered that March 8 is late for taking juniper cuttings.

Seeds

Perennials:—Various types of seeds were treated with growth substances January 12, 1940, to determine their effects on germination and subsequent growth. Each variety was represented by three lots of 50 seeds each. Two lots were treated with naphthylacetamide and indoleacetic acid respectively, mixed with thiourea and talc in the following proportions: 7 parts growth substance, 3 parts thiourea and 20,000 parts fine talc. The third lot was used as a control.

The growth substances were applied to the seeds by mixing them together in a test tube so that only a light coat of the mixture adhered to the seed. Following is a list of the perennials that were tested:

*Achillea ptarmica**
Alyssum saxatile
Anemone pulsatilla rubra
Anthemus kelwayi
Aquilegia Crimson Star
*Asclepias tuberosa**
Aubretia Monarch Mixture*
Boltonia asteroides
Cheiranthus linifolius
Coreopsis Double Sunburst
Delphinium Martin's Stock*
*Dianthus alpinus alwoodi**
Digitalis Glox Rose
Erigeron coulteri
Geum Orange Queen
*Heliopsis pitcheriana**
Incarvillea delavayi
Liatris pychnostachya
Lobelia cardinalis
Lupinus Blue King (8 seeds per plot)
Lupinus Rose Queen
Lychnis Arkwright Hybrids
Matricaria Dwarf Golden Ball
Oenotheria Youngi
Papaver nudicaule Stanford's Giant*
Penstemon gloxinoides Sensation
*Platycodon mariesi**
Polemonium richardsoni
*Potentilla nepalensis**
Pyrethrum James Kelway*
Pysostegia virginica rosa
Rudbeckia Autumn Forest
Saxifraga cordifolia
Silene saxifraga
Veronica longifolia hendersoni
Viola Arkwright rubra
*Viola Chantreyland**

For each lot, the first date of germination was recorded and thereafter daily germination counts were made. The effects of treatment with growth substance were considered significant in only 11 cases.* Considering these 11 types, *Achillea ptarmica* and *Delphinium* Martin's Stock were best when treated with naphthylacetamide. The control gave much the best results with *Aubretia* Monarch Mixture, *Heliopsis pitcheriana* and *Platycodon mariesi*. The other six gave the best results with indoleacetic acid treatments. The average date of germination of 21 types showed the treated seed slightly advanced over untreated seed. Here again indoleacetic acid showed some advantage over naphthylacetamide. With 12 types the controls germinated first and with four types there was no significant difference between the treated and untreated lots.

Since a few of the plants showed later differences in growth, samples were taken April 1. From 2½-inch pots the five best plants were selected from each lot of *Anthemus kelwayi, Dianthus alpinus alwoodi*, and *Pyrethrum* James Kelway and fresh and dry weights of tops and roots were recorded.

The effect of the treatment was significant with *Dianthus alpinus alwoodi* and *Pyrethrum* James Kelway. With these two plants, naphthylacetamide was more effective than indoleacetic acid in stimulating subsequent growth. With *Pyrethrum* James Kelway, for example, the naphthylacetamide gave an 84 per cent increase in dry weight.

Since the results obtained in the foregoing tests were not conclusive, it was thought that the concentration of the growth substances might not be strong enough. Therefore, it was decided to increase the concentration. In addition, in order to check the method of application, the usual method was compared with the actual sowing of seed and dust together. Naphthylacetamide in a mixture with talc was used as

the growth promoting agent. The amount of growth substances applied was uniform in all cases. The seeds were planted March 1, 1940.

The results obtained indicate that the application of the substance directly in the row, either of the strong (1-500) or weak concentrations (1-2000), has a retarding effect upon both the germination and subsequent growth of the seedlings. In the case of the application of the substance to the seeds, the results follow quite closely those of the first tests.

Woody Plants:—Seeds of *Clematis tangutica* and *Azalea kaempferi* were given the same treatments as the perennials. No really significant differences were noted. Several species of woody plants, including *Cotoneaster divaricata, foveolata, Diospyros virginiana, Ginkgo biloba, Ilex opaca, Juniperus procumbens* and *Viburnum lantana*, displaying various types of delayed germination, were treated with talc mixtures in the proportion of one part active substance to 500 parts talc. Only *Diospyros virginiana* and *Ginkgo biloba* gave any differences in germination. Although there were some differences in rate of germination and subsequent growth, in favor of the treatment, these differences were not significant.

One possible reason for the small amount of positive evidence gathered in this study with seeds may be the highly alkaline condition of Columbus water. This possibility is now being investigated.

Carnation Variety Patrician in Various Nutrient Solutions and Substrates (Progress Report[1])

By GEORGE A. BEACH, *Colorado Experiment Station, Fort Collins, Colo.*

CARNATIONS are the most important single crop in Colorado greenhouses. Experimenting with greenhouse crops in nutrient solutions, several workers have reported more satisfactory results with carnations than with other crops. It is worth while, therefore, that Colorado growers know the commercial feasibility of this method.

An ordinary greenhouse bench was waterproofed and planted April 4 with variety Patrician. The bench was partitioned in order to compare several different substrates including sand, gravels, charcoal, carbon, quartz, and Vermiculite which were automatically subirrigated three times daily from separate reservoirs (once daily in winter).

No attempt was made to grow these plots as pure cultures, since results were sought which would have direct application to commercial greenhouse production.

The surfaces of the substrates were not darkened, and algae grew freely (especially on sand, quartz, and carbon). Tap water and inexpensive chemicals were used. Springtails (Collembola) soon appeared in several different substrates. An attempt was made to control them by nicotine spot fumigation while the plots were flooded and again by leaching with nicotine spray solution. These treatments were ineffective, and soon considerable numbers of these insects could be found in all plots. This, of course, adds another variable, but is a condition which at least in this area would probably be a factor in commercial production in nutrient solutions.

Ten different substrates, including soil for a check, and 10 different solutions were compared on 240 plants spaced 7 inches by 9 inches in 30 plots. Seven substrates were arranged in three systematic replications and were planted from 2-inch pots on April 4. They were:

1. Soil (steamed bench soil).
2. Vermiculite (¼ inch) (A heat-treated mica sold for building insulation).
3. Wood charcoal (¼ inch).
4. Cokettes (oil-retort carbon briquettes crushed to: dust to ½ inch).
5. Coarse gravel (¼ to ½ inch).
6. Fine gravel (⅛ to ¼ inch).
7. Sand (propagating sand which retained some silt after several washings).

In addition to these were: one plot each of quartz (¼ to ½ inch) with charcoal ½ inch deep over the surface; quartz (¼ to ½ inch) to which was added 1 per cent by weight of bentonite; cinders from bituminous coal; and six additional sand plots with various solutions.

All plots were subirrigated three times daily through a ¼-inch

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drain pipe, except the three soil plots and one of the Vermiculite plots. Soil plots were given surface waterings when needed (tap water once every 5 to 10 days) and were once top-dressed with nutrient solution salts. The Vermiculite plot was subirrigated only once every 5 to 7 days.

Fresh solutions were made up every 2 weeks, and at the time of changing solutions all plots except one sand plot were leached by watering the surface of the substrate with the hose and wasting the leachings through the drain. Except in the one sand plot which was never leached, water was added as needed to maintain a 5-gallon level in each reservoir by putting the water on the surface of the substrate. In the unleached sand plot, the water was added to the reservoir only.

For 1 month after benching, Ohio WP solution (1) was used. Thereafter 2 WP and variations of this formula were used. Iron sulphate, magnesium sulphate, and boric acid were added only once every 2 weeks when solutions were changed, except for a 2-weeks period during which iron chloride was added daily to six plots, and at another time when surface applications of small amounts of iron citrate were made to five additional plots. All replicated plots, and one quartz plot, were irrigated with the regular formula.

The following variations of the regular formula were used on one plot each: High N and K, double the amount of N and K and half the amount of P; Low N and K, half the amount of N and K and 2 times the amount of P; Low N, one-fourth the amount of N; Low P, one-fourth the amount of P; Low K, one-fourth the amount of K; 2 WP + ammonium sulphate; and 2 WP − gypsum.

Minus leaching and reducing number of irrigations were considered as different formulae, even though the regular formula was used. After October 5, the amounts of all salts in all plots were reduced by one-half, thus changing the regular solution from 2 WP to WP and others in the same proportion.

No ill effects were noticeable by November on the single plot which was never leached between changes of solution.

Diphenylamine tests for nitrogen in the solutions were made every few days. The Truog quick test for phosphate and the Spurway test for potash were also made, though less often than the nitrate test.

A Beckman pH meter with electrodes immersed in the solution was used in pH determinations. The pH of the fresh solution was 6.1. No adjustment for pH was made, but at the beginning of the experiment the pH range was from 8.8 on charcoal to 4.4 on quartz. By November the charcoal plots tested from 6 to 6.3 and quartz 4 to 4.3. All plots except carbon and quartz were above pH 6.5 at the start, but by November practically all were between 4 and 5.5.

The last pinch was given July 19. An average of 4½ pinches per plant was made and the range was from 3 to 6. All plants had been pinched twice previously, and at the second pinching the range was from 2 to 7 with an average of 3¾.

The several forms of iron and rates of application used made no apparent change in the plants. As others have mentioned, the frequent addition of iron seems unnecessary with carnations in nutrient solu-

tions. Olsen (2) has suggested the possibility of precipitation of iron within the plant when the phosphate content of the nutrient solution is high. However, the sand plot in this experiment operating on low N and K had a P content 4 times higher relatively than the regular solution, yet this plot was the best one of the 30 after 8 weeks of cutting.

An indication of the difference in performance of the different substrates is shown by the fact that after 10 weeks of cutting, the average cut per plant for all treatments on the whole bench was 1½ flowers, while that of the best plots was double this number. Cutting started October 5.

The soil plots were not an adequate check in this series. Subirrigating was tried at first, but left them so wet and packed that surface watering was necessary thereafter. Even with frequent light surface irrigations soil packed badly. Once in the midsummer a top dressing of the same kind and amount of salts used in the nutrient solution was added; otherwise, tap water only was applied to the soil plots. These plants made rather poor growth and were as slow coming into bloom as were those in the carbon plots.

All things considered, by November the sand and Vermiculite had produced the best growth. Vermiculite is so retentive of moisture and at the same time so well aerated that the application of nutrients once a week will keep the plants growing nearly as well as those in the two other Vermiculite plots which are subirrigated 21 times weekly. Possibly some intermediate number of irrigations would make Vermiculite a more efficient substrate than sand.

In the charcoal plots phosphate tests were uniformly lower than those in the regular solution, even after the addition of greater amounts of phosphate. Possibly it would have been desirable before planting to have soaked this charcoal in a phosphate solution. However, after the original high pH of 8.8 had lowered to around pH 6, plant growth was better.

The carbon supported the poorest growth of all plots, but after the concentration of solution was halved in October these three plots made a quick recovery from what a month earlier looked like certain failure.

On the gravels, plants made good growth but the poorest plants were those in the coarsest gravel.

On the pure quartz carnations did so poorly in this test that one plot was replaced by sand. Bentonite was added to one, and a ½-inch layer of charcoal was applied to the surface of the third quartz plot. After the charcoal was added the plants grew fairly well. However, the most marked response was where bentonite was added; this plot by November was one of the best. Such marked improvement, together with the fact that a somewhat silty sand gave excellent growth, suggests that the presence of a colloid may be an important factor in the production of carnations in nutrient solutions. Gile (3) showed a 56 per cent average increase in millet yields by the addition of 1 per cent soil colloids to pure quartz sand and a marked increase in yield with less than 0.2 per cent colloids.

So short a time after flower production began is probably too soon

to expect differences to show as a result of the various solutions (described above on five extra sand plots), since all elements are probably present in excess in all solutions.

Even before the first flowers were cut, the low nitrogen plot showed paler foliage color, shorter growth, and fewer stems. High NK and low NK looked equally good through the summer, but after 10 weeks of cutting, high NK had produced 17 flowers, while low NK had produced 24.

The slightly pink markings which appear naturally in Patrician carnations are much more pronounced in several treatments. Early observations suggest that this variation in flower color may be an indicator of unbalance in the solution.

Sand and Vermiculite, by November, were the highest producing substrates. Fine gravel was better than coarse gravel. Carbon was the poorest. Quartz was one of the poorest substrates until bentonite was added — then it became one of the best. This fact, coupled with the fact that the sands used were slightly silty, suggests that colloids may be an important consideration in selecting the substrate and operating "sand cultures".

At the conclusion of this test it is planned to eliminate all but one or two substrates and test the promising solutions with further replication.

Apparently just as good or better carnations can be produced by this method than on soil, but each attempt to standardize methods uncovers needs for more experimentation.

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Inheritance in the Carnation, Dianthus Caryophyllus
II. Inheritance of Nine Abnormal Types

By GUSTAV A. L. MEHLQUIST, *University of California, Los Angeles, Calif.*

IN THE course of studies on the inheritance of flower color in the carnation, several abnormal types have been recorded. Some have occurred in sufficient numbers to permit a genetic analysis of their inheritance. None of these abnormal types is of economic importance in itself, but their elimination from commerical breeding stock is desirable, since obviously their presence materially increases the number of seedlings required to provide a reasonable chance for the occurrence of a desirable type. Where such elimination is not practicable a knowledge of the inheritance of such types is of value as a partial basis for estimating the number of seedlings that should be grown.

ALBINO AND YELLOW SEEDLING VERSUS GREEN

Albino seedlings have occurred in several cultures in the ratio of one albino to three green. Yellow seedlings have also occurred in several cultures in approximately the same proportions. In one culture, however, both albino and yellow seedlings occurred (Fig. 1A). As shown in Table I, the proportions approximate 9 green: 3 yellow: 4 albino, indicating that both albino and yellow differ from normal green in a single recessive factor, the double recessive also being white. The factor for albino seedling has been designated *alb* and the factor for yellow seedling *yel*. Both the albino and yellow seedlings die in the cotyledon stage.

LUTESCENT SEEDLING VERSUS NORMAL

In several lines derived from crosses involving the commercial variety Betty Lou lutescent seedlings have occurred. They are characterized by greenish yellow color and weak growth. Most of them die in the cotyledon stage but some linger on until the seventh or eighth pair of leaves. None has ever reached maturity. The segregation for this type has always been approximately 3 normal to 1 lutescent, indicating that lutescent differs from normal in a single recessive factor. This factor has been designated *lut*.

CLUB-NECK VERSUS NORMAL

In some 1939 F_2 and F_3 populations from crosses involving the variety Ivory and its derivatives many plants died at an early stage of development, most of them when only 2 or 3 inches high. On examination it was found that the upper portion of the root was greatly enlarged or swollen (Fig. 1B). When the root was sectioned it was

TABLE I—NUMBERS OF GREEN, YELLOW AND ALBINO SEEDLINGS IN CULTURES

	Green	Yellow	Albino	Total	Seeds Planted
1938	89	27	41	157	200
1940	79	30	43	152	160
Totals	168	57	84	309	360
Calculated 9:3:4	174	58	77	309	—

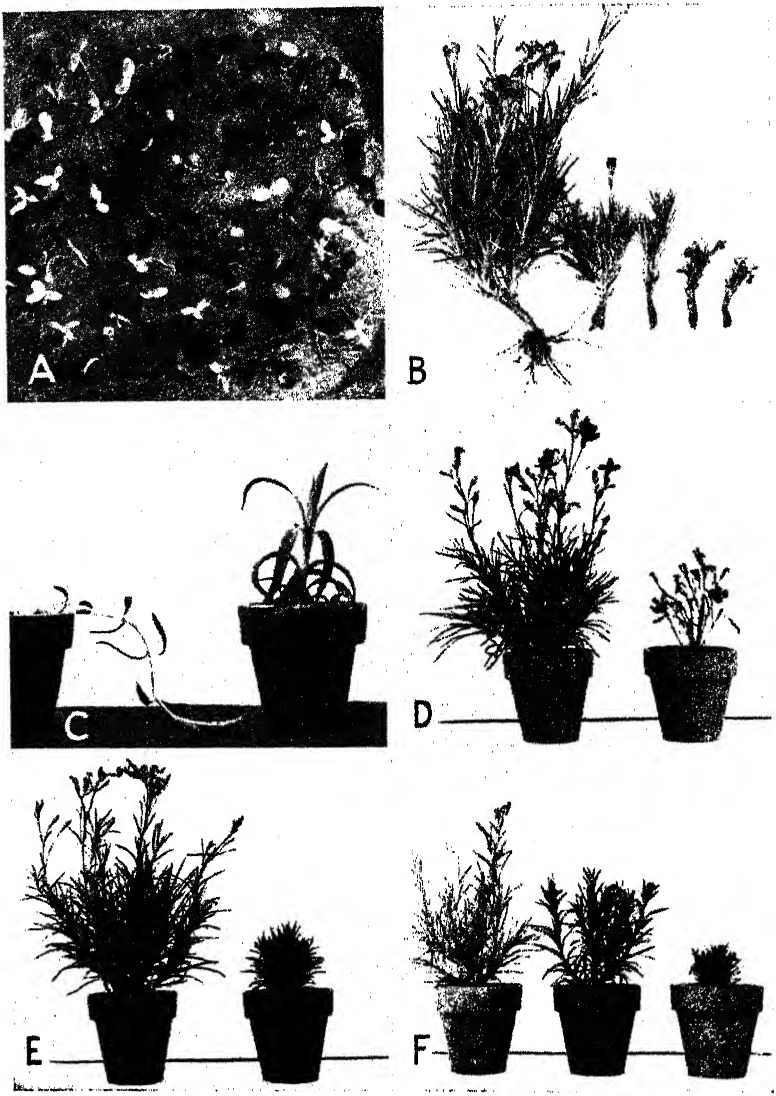

Fig. 1. A, Segregation for albino and yellow seedlings. B, One normal and four "club-neck" plants. C, "Lazy-virescent" and normal seedlings, 10 weeks old. D, Normal and "thin", 6 months old. E, Normal and "dwarf", 8 months old. F, Normal, "stocky", and "dwarf", 8 months old.

found that the inner portion was already decayed leaving a large cavity. The same condition was found to hold in the few plants of this type that still were alive, that is, only a thin outer shell of the root in this region appeared to be functioning.

TABLE II—NUMBERS OF NORMAL AND CLUB-NECK PLANTS

	Normal	Club-Neck	Total	Seeds Planted
F_1	41	0	41	50
Segregating F_2				
38578-15	141	42	183	200
38578-18	140	36	176	200
38579-7	124	43	167	200
Total F_2	405	121	526	600
Calculated 3:1	394.5	131.5	526	—

When these cultures were repeated this year (1940) it was noticed that many seedlings already in the cotyledon stage had swollen hypocotyls. A number of these seedlings were separated from the normal and transferred to the field separately. A few were retained in the greenhouse. More than 75 per cent of these died within 3 months; all but three were dead at the end of 6 months, only one of them bloomed. Since all seeds were planted in sterilized soil, and the seedlings retained in the greenhouse were grown in the same medium, it can hardly be a case of inherited susceptibility for any soil-borne pathogen. More probable is an inherited tendency to some physiological disturbance resulting in the swelling and eventual death of the tissue in the hypocotyl region.

This abnormal type has been termed *club-neck*. As shown in Table II where three lines segregating for this type are summarized, the results indicate a single factor difference between "club-neck" and normal. This factor has been designated *cb*.

VIRESCENT VERSUS NORMAL

In F_2 populations from crosses involving the commercial variety Maine Sunshine several abnormal types have occurred. One of these has been termed *virescent*. This type is characterized by a distinct deficiency in chlorophyll, usually in narrow longitudinal stripes on the leaves and stem giving the plant a variegated appearance. Rarely is this deficiency observed in the cotyledon stage but it becomes pronounced with the appearance of the next few leaves. Under field

TABLE III—NUMBERS OF GREEN AND VIRESCENT PLANTS

	Green	Virescent	Total	Seeds Planted	Green Per 100 Seed	Virescent Per 100
		1939				
38629-4	66	22	88	100	66	22
38637-15	66	18	84	100	66	18
38638-23	75	22	97	100	75	22
Total	207	62	269	—	—	—
Calculated 3:1	202	67	269	—	—	—
		1940				
38629-4	126	28	154	200	63	14
38637-15	210	57	267	300	70	19
38638-23	150	17	167	200	75	8.5
Total	486	102	588	700	—	—
Calculated 3:1	441	147	588	—	—	—

culture the growth of this type is greatly retarded and it seldom blooms. In the greenhouse, on the other hand, several plants have bloomed. The flowers have been normal in color but seldom produce stamens and so far have set no seed either when self-pollinated or crossed with normal. The results obtained in 1939, Table III, certainly indicate a single factor difference between virescent and normal green. The 1940 results are not in very good agreement with this hypothesis but it is evident that this difference is due to a decrease in the virescent group while the number of green per hundred seeds planted is approximately the same. Since both plantings were made with seed grown in 1938, it appears probable that this discrepancy is due to a lower longevity of the virescent seeds. This factor has been designated *vir*.

Lazy-Virescent Versus Normal

"Lazy-virescent" (Fig. 1C) is another chlorophyll deficient type differing from the preceding chiefly in the following characteristics. The chlorophyll deficiency does not occur in stripes but in a rather uniform dilution accentuated toward the edges of the leaves. The stem is nearly white and the internodes are greatly elongated resulting in a weak, viny plant seldom surviving more than a few weeks under field culture. This type has occurred in one line only but several cultures of this line have been grown. The results have always been approximately three normal to one deficient indicating a single factor difference. This factor has been designated *laz*.

Dwarf Versus Normal

"Dwarf" (Fig. 1E) is characterized by extremely short internodes resulting in a very short plant. One dwarf plant occurred in 1935 in a F_2 population of 243 plants. In 22 F_3 populations grown in 1937 totalling about 1,500 plants four segregated for "dwarf". Dwarf plants have since occurred in numerous other lines. Because a low frequency of these dwarf plants in some lines were correlated with relatively low seed germination, special effort was made in 1939 to increase the germination in these lines. The results, summarized in Table IV, indicate that this dwarf differs from normal in only one factor. This factor has been designated *dw*.

Because "dwarf" rarely yields any pollen and so far has produced few seeds, direct crosses between this type and normal have not yet been made.

Stocky Versus Normal

"Stocky" plants (Fig. 1F) are characterized by relatively short but

TABLE IV—Normal and Dwarf Plants

	Normal	Dwarf	Total
1937 4 F_2	224	65	289
1939 6 F_2	234	65	299
Total	458	130	588
Calculated 3:1	441	147	588

TABLE V—NORMAL AND STOCKY PLANTS

		Normal	Stocky	Total
F_2	1	65	22	87
	2	178	64	242
	3	217	72	289
Total		460	158	618
Calculated 3:1		463.5	154.5	618

thick leaves and internodes, very short calyx, relatively short and twisted petals, greatly shortened and thickened stigmas, few, usually abortive stamens. This type has also occurred in several lines. Because it is as infertile as "dwarf", only indirect crosses involving this type have been made by crossing normal plants heterozygous for this character with homozygous normal plants. The results summarized in Table IV indicate a single factor difference between this character and the normal type. This factor has been designated *sto*.

Because of the fact that both stocky and dwarf plants have occurred in the same populations the factors responsible for these types cannot be allelomorphic. Not sufficient numbers of these populations have been grown, however, to establish whether the factors are independent or linked.

THIN VERSUS NORMAL

"Thin" (Fig. 1D) is characterized by the total absence of the vegetative shoots at the base of the plant necessary for the production of the more or less continuous crop of flowers typical of the normal type. It comes into full bloom 3 to 4 months from seed whereas the normal type requires from 5 to 8. If allowed to set seed, it generally dies after maturing the seeds. If the flowers are removed, one or two weak shoots may develop below the cut but they form buds almost immediately.

This type first occurred in the plantings at Davis in the summer of 1937 in three closely related lines. The ratio of normal to "thin" was approximately 4:1. It was noticed, however, that many plants had died in these cultures during the abnormally severe freeze which occurred in January of 1937 throughout California. In fact when the number of empty spaces was added to the number of "thin" an almost perfect 3:1 ratio was obtained. When these cultures were repeated under more favorable conditions in the summer of 1938 reasonably close approximations to a 3:1 ratio were obtained. The F_1 plants grown from crosses made between "thin" and normal were indistinguishable from normal lines not segregating for this character. The F_2 results, summarized in Table VI, indicate that "thin" differs from normal in only one factor.

It is interesting that "thin" which is essentially an annual type

TABLE VI—NORMAL AND THIN PLANTS

	Normal	Thin	Total
F_1	14	0	14
F_2	177	55	232
Calculated 3:1	174	58	232

should differ from the normal, which is perennial, in only one factor. Although no cytological examination has been made of "thin" the possibility that this type is due to elimination of a chromosome or a fragment of a chromosome carrying a series of factors, several of which might be concerned with this character, is precluded by the circumstance that this type is fully as fertile as the normal. In fact, this year (1940) many thin plants were observed with a full capsule of seeds for every flower produced, a feature seldom observed in any of the normal lines.

If in a native stand of a perennial species of Dianthus, an annual type similar to "thin" should arise through mutation and then through the forces which are effective in guiding evolution should become isolated from its parental form, one might, in the absence of genetic evidence to the contrary, be forced to consider it a distinct species.

Discussion

Widely grown commercial varieties have attained their status by virtue of being the best available in their respective classes, though generally far from perfect, so it is only logical that they should be used extensively in breeding work directed toward better and perhaps different carnations. However, due to the prevalence of abnormal types, most of which can be traced directly to well-known commercial varieties or their immediate derivatives, it would seem highly desirable to have on hand for breeding purposes strains which are free from factors causing undesirable types and at the same time possess commercially desirable colors. Present evidence indicates that such properly chosen strains when crossed to proved commercial varieties give larger percentages of commercial types than can ordinarily be expected from intercrossing commercial varieties directly. Not only are there fewer distinctly useless types, but also, since the inheritance of color in the carnation is now at least partially known (1) the color of the progeny can, within reasonable limits, be predicted. The development of such strains of known genotypes is now under way at this station.

Summary

Genetic evidence is presented relative to the inheritance of nine abnormal types of the carnation. Each type differs from the normal in a single recessive factor. The factors are as follows: *alb*—albino seedling, lethal; *yel*—yellow seedling, lethal; *lut*—lutescent seedling, lethal; *cb*—"club-neck", nearly always lethal; *vir*—"virescent", a chlorophyll deficient type, sub-lethal; *laz*—"lazy-virescent", a weak chlorophyll deficient type, sub-lethal; *dw*—"dwarf", extremely short plant, less viable than the normal type, highly sterile; *sto*—"stocky", short stocky plant, somewhat less viable than the normal type, highly sterile; and *th*—"thin" an annual type, less hardy than the normal type but fully as fertile.

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Othake Sphacelata—A New Garden Annual

By W. D. Holley, *University of New Hampshire, Durham, N. H.*

ACCORDING to Rydberg (4), the genus Othake was first described by Rafinesque, while the species, sphacelata, was named by Nuttall (1) in 1827. Gray (2) described the plant under the name of *Polypteris hookeriana* in 1883. This plant is also to be found in literature under the name of *Palafoxia hookeriana*. Standardized Plant Names for 1923 gives *Polypteris hookeriana* as the preferred name. The fact remains that Rydberg (3), in an earlier work, listed this plant as Polypteris, but in his latest work (4) changed it to Othake, the name accepted by the New York Botanical Garden.

The description of *Othake sphacelata* (Nutt.), a composite, given by Rydberg (1) is as follows: Erect glandular annual herbs. Leaves alternate, mostly entire. Heads corymbose or paniculate. Inflorescence campunulate to obconic; bracts narrow, in 1 or 2 series, herbaceous, usually colored, at least at the tips. Receptacle small, flat, naked. Ray-flowers pistillate, fertile; ligules purple or rose-colored, broad, 3-cleft. Disk-flowers fertile; corollas pink or rose, 5-divided almost to the tube. Style-branches filiform, pubescent throughout. Achenes linear to narrowly obpyramidal, 4-angled. Pappus of 6–12 lanceolate, strongly ribbed squamellae.

Rydberg describes another species, *Othake macrolepis* (Rydb.), which differs from *O. sphacelata* only in that it has dicoid flower heads and leaves that are narrowly linear, while *O. sphacelata* has radiate flower heads and leaves lanceolate to linear-lanceolate. The only consistent difference other than leaf width lies in the absence of ray-florets in *O. macrolepis*. It is extremely doubtful whether this difference is sufficient to separate the two forms into distinct species, since the radiate form is naturally cross pollinated by the discoid form. The disk-flowers are self-pollinated, as in the tomato, but the ray flowers, being pistillate, and opening first, may be cross pollinated.

Seed of Othake were collected by the writer in Western Texas in 1938 and planted in Michigan the following spring. From this seed seven plants were obtained. Two of the plants were of the radiate, broad-leaved form and five were discoid, with narrow leaves. Both forms were self-pollinated by caging and seed were saved from open pollinated plants. These seed selections, planted the following spring, came true to their parents regarding form of flower and leaf character, with the exception of the open pollinated, radiate type. The progeny of this selection was 42 radiate and one discoid. This indicates that the chance of natural crossing is not too great to permit open pollinated selections in the field and greatly simplifies the improvement of this plant.

A mass seed selection of Othake was planted in July 1940 at Durham, New Hampshire. This row was rogued of undesirables, primarily the discoid type, and a number of promising variations were selected. Also a good mass selection was taken for future planting.

Variations in size of ligules and earliness were given special attention. The common number of ligules was 5, however, some plants had 6, 8 or 10. The size and number of ligules greatly increases showiness and value as an ornamental.

The *Othake sphacelata* grows 15 to 25 inches in height and about equal in spread. Its rose colored flower heads are 1 to 1½ inches across, in clusters of 4 to 8. Plants were in bloom in 1940, 5 weeks after seed was sown and continued blooming until heavy frost.

In tests, Othake has proven adapted to a wide range of soils. Although indigenous to alkaline soils of the sandy plains, it has grown well on neutral and acid soils, both heavy and light. Being a semi-desert plant it is drought and heat resistant, however, the cool summer climate of New England is not detrimental to its growth. *Othake sphacelata* gives much promise as a border plant, for cut flowers and for everlasting flowers.

Seed in limited quantities is available for wider testing.

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Treatment of Easter Lily Scales to Expedite Propagation (Preliminary Report)

By D. Victor Lumsden and Neil W. Stuart, *U. S. Horticultural Station, Beltsville, Md.*

FOLLOWING recommendations made by Griffiths (1) and Tincker (2) scales of *Lilium longiflorum* were propagated at a temperature of 80 ± .5 degrees F and a relative humidity of 75 ± 5 per cent. The scales propagated most readily when set with the bases down and one-half buried in sharp sand. The sand was kept moist but not wet throughout the propagation period. Scales from bulbs barely past anthesis to those whose tops had completely dried down all gave a good propagation. However, bulbs that had been dried to the extent that the scales were not turgid propagated poorly. Scales were thus propagated in August and September. After 1 month in sand at 80 degrees most of the scales had one to several bulbils with roots at their bases. The scales were then transferred to soil under glass where growth continued during the winter. With this treatment some scales produced bulbs that flowered within a year from the scaling operation. This procedure is not practical for routine commercial production but can be recommended for hastening propagation in experimental programs involving breeding and the rapid increase of clonal populations.

Scales were also placed in Dutch beds in the open field in August, 1939. They were "sown" 2 inches deep, disregarding position of the scales. The rows were 3 feet long with an average of 70 to 80 scales to the row. Some of the newly formed bulbs had produced leaves aboveground before winter set in. Others did not bear leaves until the following spring. In the late fall the beds were covered with a straw mulch for winter protection. Despite an unusually severe winter the bulbs were not injured and the 1-year-old bulbs were dug and replanted in August, 1940. Approximately 11,000 scales were planted in this test and over 11,300 bulbs were harvested. The circumference of these harvested bulbs varied from 4 to 12 centimeters with an estimated average between 6 and 8 centimeters. The stock from which the scales were obtained comprised many small bulbs from a number of variable seedling progenies. Working with uniformly large bulbs it is probable that this propagation could be excelled.

Greenhouse tests have shown that Easter lily scales are very responsive to treatments with the root inducing chemicals. The principal effect observed has been greatly increased root production on scales treated with talc mixtures or aqueous solutions of the growth substances. Scales treated with mixtures containing 0.5 to 10 milligrams of indolebutyric acid per gram of talc have produced far more uniform and heavier roots than those not treated or given talc alone. Similar responses have been obtained by immersing the basal portion or the entire scale in aqueous solutions containing 10 to 100 milligrams of indolebutyric acid per liter (3). Naphthyl acetic acid and naphthyl acetamide are also effective in stimulating the rooting of lily scales. These compounds appear to be somewhat more toxic than equivalent

amounts of indolebutyric acid and accordingly should be used at lower concentrations. No delay or reduction in bulbil formation has been observed as a result of treatment with favorable concentrations of the root inducing chemicals. Field tests with the growth substances involving more than 25,000 scales are now in progress.

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Effect of Mixtures of Oxygen and Carbon Dioxide on the Development of Dormancy in Easter Lilies

By N. C. Thornton, *Boyce Thompson Institute for Plant Research, Yonkers, N. Y.*, and E. P. Imle, *Cornell University, Ithaca, N. Y.*

Abstract

The complete paper will appear in the *Contributions from Boyce Thompson Institute.*

Bulbs of *Lilium longiflorum* variety giganteum were held in storage for 42 days at 25 degrees C and 28 days at 3.5 degrees C in 0, 2, 5, 20, and 40 per cent of oxygen mixed with 0, 10, 20, and 40 per cent of carbon dioxide and the necessary amount of nitrogen to give 100 per cent in each treatment. Following this treatment the bulbs were planted in the greenhouse and growth measurements were made weekly until flowering. The data show that subsequent growth from the bulbs was not affected by oxygen percentages from 2 to 40 per cent but that 0 per cent was detrimental. The presence of 40 per cent of carbon dioxide with 2 to 20 per cent of oxygen causes a retardation in shoot emergence and in growth and flowering of the plants produced.

Responses of Coniferous Evergreens to Fertilizer Applications

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IN a previous report (2) the authors have described the growth responses of American pyramidal arborvitae (*Thuja occidentalis,* L. var. *pyramidalis*) and Irish Juniper (*Juniperus communis* L. var. *hibernica*) plants which had received various fertilizer treatments under nursery conditions over a 2-year-period (1935–1937). The present report is concerned with further records on the same plants, extending over a period of 4 years (1935–1939) under the same fertilizer treatments.

The soil on which the experiment was conducted is a rather heavy silty clay loam situated on the station grounds at Beltsville, Maryland and is in the Atlantic Coastal Plain region. The soils of this region are often found relatively low in available nitrogen, phosphorus and potassium.

A detailed description of the layout of the plots, materials and methods may be found in the earlier report. Briefly, the plots planted in 1933 consisted of 20 plants in four rows of five plants each, spaced 14 inches apart in rows 3½ feet apart. A distance of 5 feet existed between plots. Four tiers of 10 plots each permitted 10 fertilizer treatments each replicated three times. The four plots per treatment were located systematically. Fertilizer applications were started in the spring of 1935 after the plants had become established.

At the end of the 1937 growing season, the arborvitae plants had started to crowd within plots. To alleviate this condition, alternate plants were removed and set in the same relative position 2 feet apart in rows 3½ feet apart within new plots on an adjacent piece of ground. The eight plants so removed from each plot were given the same fertilizer treatment as they had been receiving prior to transplanting. No changes were made in the fertilizer treatment on the 12 remaining plants in each of the original plots.

The Irish Juniper plants, having a columnar growth habit, showed no evidence of crowding within plots and so the 20 original plants per plot were left intact throughout the experiment.

The fertilizer treatments as shown in Tables I, II, and III, may be described as follows: The checks received no fertilizer. N_1, N_2 and N_3 refers to 200, 400 and 600 pounds per acre of nitrate of soda, respectively, or, where stated, an equivalent amount of nitrogen in the form of urea or sulfate of ammonia; phosphorus and potassium (P and K) were used uniformly at the rate of 800 pounds of superphosphate and 400 pounds of muriate of potash per acre. The cow manure, free of bedding or foreign material, was used at the rate of 10 tons per acre. The above amounts were applied twice yearly, one application as plant growth started and the other near the first of August. All fertilizers

were of the usual commercial grade; applied without filler in an 8-inch band 4 inches away from the plant on two sides.

The growth of the plants was recorded by circumference and height measurements. In order to give proper weight to each measurement the data were calculated on a cubic inch volume basis.

In determining the significance of the results, the data were treated by analysis of co-variance. A positive correlation exists (within treatments) between size of tree before and size after treatment, amounting to + .589 for the non-transplanted and .779 for the transplanted arborvitae, while for the Juniper this correlation was + .316. In view of this influence of size before treatment on final size, and because the size before treatment varies appreciably (Tables I, II, III), it was necessary to correct the final sizes for true comparison. To this end, the regression of Y (final size) on X (initial size) was calculated and found to be 15.842 and 15.840 cubic inches, respectively, for non-transplanted and transplanted arborvitae and 16.132 cubic inches for Juniper. These regression values, multiplied by the deviation of the number of trees in a treatment from the average initial size of the total number of plants in all treatments, constitute the corrections applicable to the final sizes.

In determining how much of the total variance was due to treatment and how much due to error, the regression influence was first removed by the formula $B^2_{yx} \times S^2_{x} - 2\,B^2_{xy} + S^2_{y}$, where B_{yx} is the regression value, S^2_{x} and S^2_{y} are the variances of the initial and final sizes, respectively, and S^2_{xy} is the corresponding co-variance. In the case of the non-transplanted and transplanted arborvitae the variance due to treatment was 8 and 6.5 times, respectively, that due to error, while with Juniper the variance of treatment was 5.5 times the variance due to error. The odds, therefore, greatly exceed 99 to 1 that significance exists among the differences due to treatment. From Snedecor's F table (4) and the calculated error of the mean difference, it was found that any differences between treatments as large as 46.73 cubic inches for the non-transplanted arborvitae, 45.41 cubic inches for the transplanted arborvitae and 37.15 cubic inches for the Juniper are significant at odds of at least 99 to 1.

Discussion of Results

The growth responses of arborvitae receiving the various fertilizer treatments are shown in Tables I and II. A significant measurable response in growth has resulted from the use of 400 pounds per acre of nitrate of soda alone, (N_2 compared with the check treatments). This amount of nitrate was too much for these same plants two years earlier and caused poorer growth than the check plants at that age. A comparison of the N_1PK, N_2PK and N_3PK treatments in Table I shows that 200 pounds of nitrate (N_1PK) was sufficient, and heavier amounts in this mixture induced no better growth. However, in the

case of comparable plants transplanted to adjacent land not previously receiving fertilizers (Table II) 400 pounds of nitrate (N_2PK) was better than 200 pounds (N_1PK), but 600 pounds (N_3PK) was definitely too much.

Phosphorus applications have caused no increase in growth of arborvitae, except when used in combination with both N and K, (N_2 compared with N_2P and N_2K with N_2PK) (Tables I and II). In other words, the need for potassium had first to be satisfied before any response to phosphorus could be obtained.

A beneficial response is shown from potassium applications to arborvitae in the original plots, N_2 compared with N_2K (Table I). Transplanted plants, however, show no such benefit from K, since the difference in growth between the N_2 and N_2K treatments in Table II is not significant. Either these plants had retained sufficient K to sustain growth for 2 years from applications received prior to transplanting or available potassium in the soil moved with the plants was sufficient for growth over that period.

At the end of 2 years no differences were detectable between the three nitrogen carriers employed. However, after 4 years' applications the arborvitae plants receiving sulfate of ammonia were significantly poorer than those in either the urea or nitrate of soda treatments of equivalent nitrogen content. pH determinations of the soil (1936 and 1938) showed these plots running much lower in pH value, ranging from pH 4.4–4.7, while the urea, nitrate of soda and check plots ranged from pH 5.0–5.6.

Although mineral fertilizers in the proper proportion have produced as large arborvitae plants as the animal manure used, with the exception of the transplanted plots, the characteristic form of the plant was affected by certain of the fertilizer treatments applied. Therefore, having in mind the ultimate sales value of the plants for ornamental purposes, each of the treatments was given a relative rating on the basis of density and form of plant produced. In this connection, the check, N_2, N_2 P, and N_2 K treatments rated best in maintaining the

TABLE I—EFFECT OF VARIOUS FERTILIZER APPLICATIONS ON GROWTH OF ARBORVITAE

Fertilizer Treatment	Average Size of 48 Plants Before Treatment (Cubic Inches)	Size After 4 Years Treatment (Cubic Inches)	Correction Due to Regression*	Corrected Final Size† (Cubic Inches)
Check (no fertilizer)	90.68	2633.5	+102.96	2736.5
N_1 PK	98.81	3686.7	− 25.81	3660.9
N_2 PK	95.12	3547.7	+ 32.63	3580.3
N_3 PK	92.95	3542.5	+ 67.00	3609.5
N_2 P	101.10	3031.0	− 62.00	2968.9
N_2 K	99.04	3376.2	− 29.46	3346.7
N_2	94.27	2897.7	+ 44.51	2942.2
N_2 PK (Urea)	98.75	3656.5	− 24.87	3631.6
N_2 PK(Ammonium Sulfate)	100.81	3530.2	− 57.49	3472.7
10 tons manure	100.22	3716.7	− 48.15	3668.6
Average	97.18			

*Correction of final size for effect of size before treatment.
†At odds of 99:1, a difference of 46.73 cubic inches, or greater, becomes significant.

TABLE II—Effect of Various Fertilizer Applications on Growth of Transplanted Arborvitae

Fertilizer Treatment	Average Size of 32 Plants Before Treatment (Cubic Inches)	Size After 4 Years Treatment 2 Years After Transplanting (Cubic Inches)	Correction Due to Regression*	Corrected Final Size† (Cubic Inches)
Check (no fertilizer)	89.68	1541.1	+ 95.04	1646.1
N_1 PK	98.00	2064.4	− 42.13	2022.3
N_2 PK	90.90	2088.6	+ 70.32	2158.9
N_3 PK	90.78	1755.0	+ 72.23	1827.2
N_2 P	100.00	1771.5	− 73.81	1697.7
N_2 K	93.53	1714.7	+ 28.67	1743.4
N_2	94.93	1761.3	+ 6.49	1767.8
N_2 PK(Urea)	102.10	2311.2	−107.08	2204.1
N_2 PK(Ammonium Sulfate)	98.43	2216.4	− 48.95	2167.5
10 tons manure	95.43	2535.0	− 1.42	2533.6
Average	95.34			

*Correction of final size for effect of size before treatment.
†At odds of 99:1, a difference of 45.41 cubic inches, or greater, becomes significant.

pyramidal character of growth and density. All the other treatments, including the manure treatment, tended to produce plants with two or more strong leaders, which altered the pyramidal shape. It is possible that corrective pruning, judiciously applied to these plants at the proper time, would overcome this difficulty.

Table III shows that all the fertilizer combinations used induced a significant increase in growth over the check plots when applied to Irish Juniper. Although the growth response at the end of 2 years' treatment had shown that Juniper is tolerant of heavy applications of nitrogen, the results over a period of 4 years indicate that 200 pounds of nitrate of soda (N_1) is sufficient, since the 400 (N_2) and 600 pounds (N_3) application caused a progressive decrease in growth, (Compare treatments N_1 PK, N_2 PK and N_3 PK) (Table III).

As in the case of arborvitae, no direct benefit from phosphorus was obtained on Juniper (N_2 compared with N_2P). However, in combination with N and K there was a significant growth increase (N_2 K compared with N_2 PK).

The very marked response of both arborvitae and Juniper from potassium (N_2 compared with N_2 K) suggests that perhaps the soil used in this study may be low in available potassium. Peach trees growing on a somewhat different soil type on the station grounds have also responded favorably to potassium applications (1).

In order to determine the relative potassium content of plants receiving check, N_2 and N_2 K treatment, samples of the foliage of both arborvitae and Juniper were taken on these plots in the fall of 1940, and prepared for potassium precipitation by the method of Sideris (3). The method of precipitation was that of Wilcox (4). Upon analysis, the foliage of the N_2 K treatment was found considerably higher in potassium content than the check and N_2 treatments with both species. The percentage dry weight of potassium was .46, .40 and .83, respectively, for check, N_2 and N_2 K on arborvitae, while with Juniper treatments in the same order the percentage of potassium was

.35, .40 and .51. Appreciation is expressed to Dr. L. P. Batjer for his assistance in obtaining these potassium determinations.

It is surprising to note that the fertilizer mixture, N_1 PK, has produced significantly larger plants than the high grade manure used on Irish Juniper in this study. A comparison of the three nitrogen carriers favors the use of nitrate of soda or urea which gave significantly better growth than sulfate of ammonia (Table III). This comparison, however, was based on a nitrogen level (N_2) that was above the optimum for best growth.

TABLE III—Effect of Various Fertilizer Applications on Growth of Irish Juniper

Fertilizer Treatment	Average Size of 80 Plants Before Treatment (Cubic Inches)	Size After 4 Years Treatment (Cubic Inches)	Correction Due to Regression*	Corrected Final Size† (Cubic Inches)
Check (no fertilizer)	52.04	1621.5	+30.96	1652.5
N_1 PK	53.39	2314.5	+23.71	2338.2
N_2 PK	53.83	2281.4	+16.61	2298.0
N_3 PK	56.64	2234.4	−28.71	2205.7
N_2 P	58.43	1915.7	−57.58	1858.1
N_2 K	56.80	2071.1	−31.29	2039.8
N_2	55.67	1882.5	−13.07	1869.4
N_2 PK(Urea)	54.48	2260.8	+ 6.13	2266.9
N_2 PK(Ammonium Sulfate)	53.74	2231.2	+18.07	2249.3
10 tons manure	52.65	2170.2	+35.65	2205.9
Average	54.86			

*Correction of final size for effect of size before treatment.
†At odds of 99:1, a difference of 37.15 cubic inches, or greater, becomes significant.

In summarizing the results of this study over a four-year period it is concluded that, under the conditions encountered, nitrogenous fertilizers in proper amounts have resulted in increased growth over no fertilizer of both plant species, but to be most beneficial, the rate of application should not exceed 200 pounds per acre; that a combination of N, P, and K is better than N alone or N in combination with either P or K; that over a period of continuous usage nitrate of soda and urea have proved better carriers to use than sulfate of ammonia, a differential response being noted with the two species in this connection; that mineral fertilizers of proper proportion may be substituted for manure; that transplanted arborvitae may be expected to respond to such a mineral fertilizer mixture; and further that the characteristic form of the plant may be altered by fertilizer application which may or may not be desirable from an ornamental standpoint.

The N_1 PK treatment used in this study has given a consistent satisfactory response with both arborvitae and Juniper. This treatment would approximate a 2–9–14 commercial fertilizer of standard grade applied in spring and late summer at the rate of 1400 pounds per acre. Individual plants under clean cultivation would receive about 3 ounces of fertilizer per application.

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Time of Harvest and Storage Conditions in the Development of Dormancy in Easter Lilies

By E. P. Imle, *Cornell University, Ithaca, N. Y.*, and N. C. Thornton, *Boyce Thompson Institute for Plant Research, Yonkers, N. Y.*

Abstract

The complete paper will appear in the *Contributions from Boyce Thompson Institute.*

Bulbs of *Lilium longiflorum* varieties Erabu and giganteum harvested at three stages of maturity were at each harvest divided into four lots for each variety and stored for 70 days, this total period being divided as follows: 14, 28, 42, and 56 days at 25 degrees C, and 56, 42, 28, and 14 days at 3.5 degrees C respectively. Following this storage treatment, the bulbs were planted for forcing in the greenhouse and growth measurements were made weekly thereafter until flowering. Lots harvested the earliest and considered immature gave a high percentage of dormant bulbs that required more than 6 months to initiate growth. Bulbs harvested when plant died showed growth in an average of 27 to 43 days. Bulbs held 56 days at 25 degrees C followed by 14 days at 3.5 degrees C were slow to initiate growth, exceedingly slow to produce a sizable plant and to flower. In contrast, bulbs held 14 days at 25 degrees C followed by 56 days at 3.5 degrees C initiated growth more readily and required a much shorter period of growth before flowering.

Vitamin B_1 vs Organic Matter For Plant Growth[1]

By A. E. Murneek, *University of Missouri, Columbia, Mo.*

DISCONSIDERING the sensational claims in popular articles, the value of vitamin B_1 for plant development has not been fully established. Marked increase in growth or rate of accumulation of dry matter has been obtained with some plants from application of this substance to sand cultures and in some cases to soil (1, 2). The optimal concentration has been found to be about .01 milligram per liter or 10 parts per million of water supplied. The beneficial effect seems to be produced chiefly, if not entirely, through stimulation of root development.

Plants differ in respect to their response to vitamin B_1. Certain species, the tomato and pea for example, apparently do not react to additions of B_1 to the soil, for they seem to be able to produce in the leaves this substance in large enough quantities, as shown by the Phycomyces assay. But an inherently low rate of synthesis of this vitamin does not always limit plant growth. More recent tests with B_1 on a wide variety of plants under highly refined technique in water and sand cultures have given negative results (3, 4). This despite the fact that several of the species used were supposed to be deficient in their capacity to form this substance and therefore to be responsive to an external supply.

In view of this situation and the general interest created in vitamin B_1, it was thought desirable to test its possible practical value as an acccessory organic nutrilite for growth of plants in soil.

Different types of plants were selected for the experiment, including a non-responsive (tomato) and a highly responsive (cosmos) species. The test was conducted during March, April, and May, which is a very favorable period in this locality for growth of plants in the greenhouse. The general set-up of the experiment and the results obtained expressed in relative growth (dry weight) of tops and roots, are presented in Table I. It will be observed from the subscript of the table that the amount of vitamin B_1 supplied was slightly above the optimal strength (.025 milligram per gallon), and five times this concentration (1.25 milligram per gallon).

The parallel test with leaf mold needs a word of explanation. Though the plants were grown in potting soil containing one-third leaf mold, it was thought desirable to put an extra ¾-inch layer of organic matter on top of some of the cultures. It has been found that organic manures contain appreciable quantities of B_1 (1) and so undoubtedly do abscissed leaves since this vitamin is synthesized in various amounts in leaves of all green plants in presence of light. The results show that while vitamin B_1 had a very significant stimulating effect on both top and root growth, equally good and in many cases even better results were obtained by the additional supply (top cover)

[1]Contribution from the Department of Horticulture, Missouri Agricultural Experiment Station Journal Series No. 714.

TABLE I—EFFECTS OF VITAMIN B_1 ON TOP AND ROOT GROWTH OF SOME HORTICULTURAL PLANTS†

Species	Length of Experiment (Weeks)	Dry Weight (Grams)				Per Cent Increase Over Control		
		Control	Leaf Mold	Vit. B_1 .025 Mg Per Gal	Vit. B_1 .125 Mg Per Gal	Leaf Mold	Vit. B_1 .025 Mg Per Gal	Vit. B_1 .125 Mg Per Gal
Top Growth								
Tomato..	8	156.0	162.1	163.2	168.5	3.9	4.5	8.0
Dill......	8	30.5	47.5	61.0	35.5	56	100(?)*	16.3
Rudbeckia..	8	40.0	52.0	38.0	42.5	30	−5	6.5
Cosmos...	8	35.5	42.5	55.0	40.5	19.8	54.9	14.1
Ornamental. peppers	8	20.0	24.0	24.5	23.5	20	22.5	17.5
Root Growth								
Tomato..	8	18.0	19.4	18.5	18.8	7.7	2.7	4.4
Dill......	8	1.6	2.6	3.9	1.9	62.5	143.7(?)*	19.7
Rudbeckia..	8	5.0	7.0	5.0	5.0	40	0	0
Cosmos...	8	4.0	4.5	4.7	4.7	12.5	42.5	17.5
Ornamental peppers	8	5.0	6.0	7.0	5.0	20	40	0

†Plants grown in 3 gallon glazed jars, with bottom drainage. Soil for all experiments: ⅓ loam, ⅓ sand, ⅓ leaf mold (potting soil). One plant per jar, except cosmos, in which case 3 per jar. Three jars in each group.

Treatments: Control—no treatment—tap water, pH 7.8; leaf mold—4 inch pot full of leaf mold on top of soil, per jar; Vitamin B_1 .025 milligram per gallon in tap water continuously; and Vitamin B_1 .125 milligram per gallon in tap water continuously.

*1 Abnormally large plant. Hybrid vigor?

of leaf mold. Organic matter of this sort, in addition to B_1,[2] of course contains many other organic and inorganic nutrient substances, including those not yet discovered.

A second group of plants, all cosmos, were tested for vitamin B_1 effect as part of a cooperative undertaking by the California Institute of Technology and Merck and Company. Seed and general directions

TABLE II—EFFECTS OF VITAMIN B_1 ON GROWTH OF COSMOS*

Treatment	Number of Plants	Length of Experiment (Days)	Average Dry Weight Per 20 Plants (Grams)		Percentage Increase Over Respective Controls	
			Tops	Roots	Tops	Roots
Control, pH 7.8........	21	30	34.2	8.2	—	—
Control, pH 6.0........	14	30	32.3	7.9	—	—
Vitamin B_1						
Sol. A, pH 7.8........	25	30	41.0	10.4	19.9	26.8
Sol. A, pH 6.0........	25	30	34.5	8.0	6.8	1.3
Sol. B, pH 7.8........	25	30	37.5	10.2	9.6	24.4
Sol. B, pH 6.0........	25	30	38.9	10.9	20.4	38.0
Leaf Mold.............	25	30	39.2	10.5	14.6	28.0

*Plants grown in 4-inch clay pots of loam soil, imbedded in sand.

Tap water—pH 7.8 Acidified as needed with acetic acid to pH 6.0.

Leaf mold, when used, ½ inch layer on top of soil.

Vitamin B_1: Sol. A, .05 milligram per gallon; Sol. B, 5.0 milligram per gallon. Applied every 5 or 6 days.

[2]Subsequent assays of this particular leaf mold by Dr. J. Bonner showed a relatively high vitamin B_1 content of 2.5 parts per million, while the soil used had but .41 parts per million and the sand no detectable B_1 content.

were supplied by J. Bonner of the above institution, but the supplementary use of leaf mold was the writer's own idea. The experiment was conducted from May 25 to June 25, when the maximum day temperature of the greenhouse ranged from 85 to 105 degrees F and the nights were correspondingly warm. Details of the test and the results obtained are presented in Table II.

Adjustment of the pH of water used came as an after thought,[3] the idea being that vitamin B_1 (thiamine hydrochloride) possibly is unstable in an alkaline solution. The water supplied to our greenhouses having a pH of 7.8, a duplicate experiment was set up with water at pH 6.0. The results show (Table II) that acidification of water had no beneficial effect, since on the average better growth of plants was obtained with tap water at pH 7.8.

Conclusions

At concentrations of .025 to 5.0 milligram per gallon of water vitamin B_1 had conspicuously beneficial, though variable, effects on growth of several plants (cosmos, dill, ornamental pepper) in both poor and rich soil, as expressed by dry weight of organic matter produced. Root development was influenced the most, thus supplying additional evidence that this vitamin is more or less specifically a root growth factor and that the rest of the plant is benefitted through an increased growth of the subterranean organs. Equally good, and sometimes better results were obtained, however, by merely putting on the surface of the soil a ½ to ¾ inch layer of leaf mold which supplied not only sufficient vitamin B_1 but undoubtedly a good many other organic stimulants (growth factors or nutrilites) including many whose importance has not yet been disclosed. In horticultural practice success with this and other growth factors would seem to depend largely upon the kind of soil used and types of fertilizers applied (5).

But why should plants growing in soil, containing by volume one-third organic matter, be still further benefitted by a top layer of leaf mold (Table I)? Is it possible that this surface dressing plus the relativly high calcium content of the water used encourage Azotobacter development? It has been reported (1) that these bacteria, among other functions, synthesize extremely large quantities of vitamin B_1.

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[3]Private communication from Dr. J. Bonner, May 5, 1940.

Some Social Implications of the Scientific Method

PRESIDENTIAL ADDRESS

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SEVERAL considerations have led me to choose the present title which I know will appear to many of you, at least at first sight, to be rather inappropriate for presentation before the American Society for Horticultural Science. Among these is the fact that our society is becoming mature. Attendance is now larger and more varied than formerly, and it seems not out of place to consider matters of a general nature rather than to continue the technical discussions of the regular sessions. Not that we should be less zealous of the pursuit of scientific knowledge, but rather that now we have established our position as a first class scientific society we can pause momentarily and examine our situation with relation not only to other scientific societies, but to the whole field of knowledge as well.

The subject is certainly timely. With most of the world at war or near war it is all too obvious that our control of physical forces has far outstripped the capacity or at least the will of the human race to manage their affairs in a satisfactory way. Such a statement is trite in view of the many efforts now being made to increase the sense of responsibility among the scientists for the social order. This trend has been emphasized recently by the National Research Council in its consideration of the obligation of the scientists of America to society in general and the defense program in particular.

It is timely also because the method and approach used by many, or should I say most, scholars in studying and attempting to solve the problems of human relationships, including economics, sociology and ethics, are at the present time apparently confused and ineffective. There has not been adequate leadership in these fields at a time when such leadership has been far more important than technological advance and control. Economic bungling of both governmental and private institutions and in industry during the past years of depression has brought out only too clearly the inadequacy of our society to handle the really important problems. It is indicated particularly by the failure among economists to have any answer upon which they can agree and no widely accepted method of approach to economic problems.

Modern ethics also is in a confused state. This was brought out most forceably in a recent course of lectures on "Ethics and Modern Life", given at Cornell by a leader in that field. The titles of some of the lectures will indicate the confusion of thoughts and ideas that apparently exists. The first title was "The Dilemma of Modern Ethics". The dilemma seemed to be that there is no way by which the problem of human conduct could even be considered. Ideas just don't have any contact with action, and every term that is used is a dilemma in itself. The second lecture was on "The Venture of Moral Philosophy". The venture appeared to be that it was most extraordinary that anyone would have the temerity to even try to do anything about conduct. The third lecture had to do with the divergence of theory and practice

in which it was again brought out that it is practically impossible to bring ideas to bear upon the world of fact and experience. In the fourth lecture entitled, "The Modern Experiment; Ideas and Immediate Experience", it looked as if the lecturer were going to arrive at something which at least faintly resembled an effective approach to the problem, the scientific approach if you please. The startling concept was advanced that possibly ideas could be brought to bear upon immediate experience. In the last lecture of the series, however, entitled, "The Persistent Tension in Experience and Morals", the idea was given up and it was indicated that the whole matter was in a condition of confusion, futility and conflict. It gave no real hope to the human race for ever doing anything effective in directly meeting their problems in the improvement of social and moral relationships which is so necessary if civilization is to continue. Yet this authority in the field of ethics received nearly $6.00 a minute for bringing his audience to such a state of confusion and impression of futility. The above picture is, of course, overdrawn and cannot be used as a basis for generalization. It does, however, contrast rather sharply with the situation where the scientific method is used as a tool in the solution of problems.

It is my belief that the method of science or the scientific approach is useful and effective in interpreting phenomena in all fields of human knowledge and endeavor and will aid in the solution of all problems with which the human race is confronted. It is also my belief that we as scientists have the opportunity, if not even the obligation, of bringing to bear upon the problems of living, both private and public, the method and approach of science. I submit that this method has had an outstanding record of accomplishment in the fields where it has been used and that the extension of its use as a working hypothesis for the solution of all problems is more practical and effective than any approach so far devised.

Before going further it is essential to make clear just what is meant by the scientific method. Here I know that much that is said will seem trite and well known to most or all of you. It is, however, necessary that such a statement be made, otherwise we do not know just what we are talking about.

Behind the scientific method are a number of basic assumptions which are taken as axiomatic. The first of these is that everything that takes place in the universe as we know it, takes place in accordance with natural law. The second is that the human mind is capable of comprehending and understanding this natural law and hence can understand the universe. If this were not true the scientist could not work. What would be the use of spending our time investigating something that we can not understand. Of course, there is much in the universe of which we are not aware, much that our senses do not perceive, but we must assume that these things could be perceived and understood if we were given, or if we devised, the proper instruments to perceive. The proof of such assumptions is that they work.

The radio is an obvious example. The natural law underlying the development of the radio has always been there. Radio waves, as such, are quite beyond the perception of any of our natural senses. However,

by understanding the nature of these waves and how to control them it is possible to translate electric impulses into sound that we can perceive and enjoy. The air at this moment is full of all sorts of programs which, I am thankful to say at the moment we do not perceive. By bringing in a radio properly tuned we are able immediately to make this apparent silence more audible.

As a further illustration of just what is meant by natural law, I might cite the periodic table of atomic weights as formulated by Mendeleyev in 1869. At that time only 70 elements were known, but on the basis of his hypothesis he postulated that there were 92 and went so far as to describe the properties of some of these that were still unknown. Within a comparatively few years 15 additional elements had been found and now I believe all have been accounted for. When it was published in the newspaper that element 87 had been discovered it was no surprise. The chemists had known all along that it was there. Another example of what we mean by natural law is the comparatively recent discovery of the planet, Pluto. Astronomers knew by the behavior of other planets that such a planet existed and it only remained for a more powerful telescope to confirm its position. Who would doubt that the laws of astronomy have existed from the first? And so it is with other natural law.

Why many fail to appreciate the implications of the scientific method is that they do not consider natural law of universal application and are inclined to limit its scope to the physical sciences or to those in which material can be accurately weighed or measured. It is here that the greatest progress has been made and it is here that the factors with which the scientist deals are capable of the best controlled manipulation. Lord Kelvin has stated and I quote, "When you can measure what you are speaking about and express it in numbers, you know something about it, but when you cannot measure it, when you cannot express it in numbers your knowledge is of a meager and unsatisfactory kind: it may be the beginning of knowledge but you have scarcely in your thoughts advanced to the stage of science". This is a very significant statement and insofar as the material concerned is capable of being measured and expressed in numbers it should apply. But certainly there is no particular virtue in numbers as such, and if the number does not honestly represent what it is supposed to represent it can be more misleading than a statement in words because the number gives an impression of accuracy that does not exist. It is my belief that some economists and biometricians have only confused our knowledge by using and manipulating numbers. Further, what is to be done with that great mass of phenomena which cannot be measured and reduced to numbers but which is far more significant and important to human living than anything in the field of physical sciences?

It might be possible to arbitrarily limit science by definition to those fields in which the material dealt with can be weighed, measured and expressed in numbers. This, however, is an untenable position because what we can measure today is far different from what we could measure yesterday and no one can venture what we may be able to measure tomorrow. To set up such an arbitrary limit implies that somewhere

in our universe there is a limit beyond which the scientific method does not apply. But there certainly is nothing in the basic assumptions of the scientific approach that would justify setting such limits. These assumptions are simple, namely that the universe operates according to natural law and we as human beings can understand natural law and hence the universe. To say that this does not have universal application is to say that part of our universe is chaos and without causal relationship between an event which takes place and the forces and conditions that have brought it about. Personally I know of no scientist or scholar that would admit that such chaos exists anywhere and I insist that it does not.

Because of this concept that nothing is really science unless it deals with things that can be measured and given numerical values there has grown up a sort of hierarchy or aristocracy among the sciences in which the physicists and the chemists hold themselves somewhat aloof from the biologist, the psychologist, the economist and the sociologist, apparently feeling that after all physics and chemistry are the only true sciences and that the others are only pseudo-science. The biologist and the psychologist because they can effectively employ the experimental method in turn are inclined to look down their noses at the social sciences as being on an even lower grade of pseudo-science. This situation has been admirably described by Professor Boynton of Chicago University in his chapter on Knowledge and Wisdom in a recent book.

Apparently much of the difficulty is based on the assumption that nothing is truly scientific unless it can be adapted to experimental treatment in the laboratory. It is true that the experimental method has been idenified with science itself from the first and rightly so, and that it is through experimentation that the outstanding advances of the past decades have been made possible. It is also true that in the fields of knowledge which deal with human relationships and aesthetics, experiments of the accepted laboratory type are difficult. This does not mean, however, that the basic principles of the scientific approach do not apply.

To emphasize this universality of natural law, it is useful to consider it as operating in different fields or at different levels. With no attempt at a complete classification we might set up a system something like this. First of all, there would be the physical level which would include physics and chemistry. The fact that chemistry in its last analysis is anatomic physics is not important for developing the concept. Next in line would be the biological level. Here we are dealing with living things such as the nature of protoplasm, the physiology of plants and animals and such matters as health, medicine, and nutrition. Here would be considered all parts of man's nature that had to do with his biology. Psychology has to do with the workings of the mind and might be regarded as a phase of biology or at least to have an intimately associated biological basis. The process of thought is more complex and of a somewhat different nature than the physiological processes of digestion or respiration and for that reason psychology may well be set off from biology as such.

The social level has to do with relations between persons both as individuals and in groups and includes economics, sociology and ethics. We might also speak of an aesthetic level or field which has to do with the appreciation of art and literature and poetry. Ethics and aesthetics merge directly into what might be termed a spiritual level. In dealing with these upper levels the concept of value comes in. Thus, we speak of economic values, moral values, spiritual values. No attempt is made to give an exact relationship of these. The point to be made is that as we progress from one level to another there is continuity. If we accept evolution as a fact this could not be otherwise.

Also as we progress from one level to another, or from one set of values to another the nature of the natural law that is operating becomes increasingly more complex. It is, however, none-the-less real because it becomes less tangible and more difficult to handle experimentally. To further illustrate the point I am trying to develop it is well to consider some of these levels in more detail. The operation of physical law is obvious and accepted. No scientist has any doubt of its validity and the same is true of natural law in the biological field. This is the level with which the members of this Horticultural Society are primarily concerned. We recognize the application of chemistry and physics to our problems. But here in the biological field a new element that is very important comes in. We are dealing with living matter or protoplasm and its behavior not only as a substance, but as it is integrated in more complex organisms. The distinctive thing about protoplasm, however, is not the presence of certain chemical elements, but rather the integration of these. Of course, the elements which enter into the composition of protoplasm are essential, but merely to mix these in any given proportion is not to have protoplasm. The important thing about this substance is its organization, a thing which we destroy as soon as we try to treat it with chemical or physical techniques. It may be that eventually protoplasm will be partially explained in terms of stero-chemistry and in last analysis atomic physics will contribute greatly to our understanding of its behavior. This, however, does not invalidate the concept. The important thing with which the biologist deals is protoplasm as such and its behavior as a living integrated functioning entity that is more than the sum of the chemical elements of which it consists.

The question of absorption of water by roots and its movement into the xylem vessels was not explained satisfactorily as long as such movement was regarded as an osmotic phenomenon carried on by purely passive physical forces. It can be explained, however, on the basis of the action of the protoplasm as a living substance which moves salts against a diffusion gradient and secretes them into the vessel in such concentration that water can then move by osmosis. In the process energy is used and work is done and this depends upon the organization and functioning of the protoplasm itself. To be sure physical laws are concerned and none has been violated though just how they work may not be too clear. The significant fact with which we are dealing, however, is the whole organization of protoplasm and cells and tissues which makes this process possible.

In the field of Horticulture the use of chemical methods has been valuable in some problems. Too often, however, the chemist, particularly if he is not a horticulturist as well, has not contributed to the solution of problems as much as hoped for because of his failure to appreciate the plant as something other than a mass of chemical elements and compounds. As horticulturists we must never lose sight of the plant as a living functioning organism that is more than the sum of the chemical elements of which it is composed, This idea was well expressed by Dr. E. W. Sinnott in his presidential address before the Botanical Society in 1938. It certainly is one that we as horticulturists should not ignore.

In biological problems, particularly in studying the physiology of plants and animals we continually use the scientific approach at least in our basic concepts and attitudes. We assume that what we observe is going on according to natural law and that we can understand it. We are so sure of this that when apparent exceptions occur we merely conclude that our conception of the natural law that is operating is wrong and that we much search further to find out what is basically involved. This approach which we all use has been adopted because of the fact that in general it works, or at least works much better than any other approach which has been devised.

An example of the use of this approach might make our meaning more clear. Some weeks ago in the greenhouse at Cornell a chrysanthemum plant normally with dark bronze flowers was observed in which a part of the flower heads were light yellow, a part dark bronze and in some heads the florets were dark in the lower part of the head and light in the upper. The question arose immediately as to the cause of this difference in color. Because of the position of the flowers, it was evident that bud mutation was not the answer. The difference in color was apparently related to the proximity to a steam pipe. Such an observation immediately suggested the possible effect of heat upon the color of the flowers in question. This, of course, is tied up with the nature of coloring matter concerned. Knowing that the color was anthocyanin and that this is a derivative of sugar, immediately the problem becomes related to the sugar supply available for the production of this coloring matter. Increase in temperature is, of course, related to respiration so that the possible explanation might be that the color pigment was absent from the flowers next to the steam pipe because of the loss of sugar through increased respiration. Another relationship indicated in the heads with dark florets below and the light above was the effect of the progressive shortening of day length in relation to carbohydrate manufacture. Heads that had color in the basal florets might have developed relatively earlier during longer days than those in the center. Under such conditions the sugar supply available at the time the florets were forming might be the controlling factor in determining the color. Doubtless other factors were also operating and in any case these hypotheses would have to be proved experimentally before acceptance.

This example merely illustrates the scientific approach to a problem. First, we ask the question, "What is it that has happened and what are

the materials involved?" Next, "What are the factors operating that might bring about the changes which we have observed?" Then, "What are the natural laws which are operating in controlling these factors?" It is my contention that this method of approach is valuable in approaching any problem.

At the psychological level we are dealing with something a little different from that found at the lower levels. Here again there is increased complexity. Nevertheless there is continuity in the natural law operating in the psychological field throughout the animal kingdom. There is no break between man and the other animals. The psychologists, of course, or at least many of them, have recognized this and have adopted the scientific method. Certainly there would be no logic in working with rats, dogs or pigs if this continuity did not exist. The natural law underlying psychological behavior seems to be relatively well understood compared to such understanding in the fields of economics and ethics. At least it is being made of practical use on a wide scale. We have only to mention such terms as "child training", "high pressure salesmanship", "propaganda" and the like to show this to be a fact. The astounding effectiveness of the Hitler regime is based largely on the control of some psychological factors. We can only hope that his knowledge is inadequate to carry out his plans in their entirety. Certainly neither the effect of bombing upon the British morale nor the imprisonment of the German clergy in concentration camps has worked out as was planned and indicates a lack of understanding of the psychology of these groups.

Here again in the psychological field we are dealing with natural law that is unlike physical law and unlike most of the natural law in the biological field also. We are concerned with human response. Attempts are made to reduce human behavior to terms of endocrine secretions, blood pressure, and similar factors. To get any significance out of human relationships, however, it is futile to reduce human behavior to such terms. The minute we try to break down a human reaction in terms of solutions and secretions the thing itself is lost. It is like trying to find out the nature of protoplasm by subjecting it to chemical analysis. As soon as it is manipulated with chemical techniques the significant thing about it no longer exists. For example, take the behavior of an affectionate child toward its father. On returning home after a separation, at the first sight of the parent the child comes running to him with every expression of eagerness and joy. Such actions are doubtless associated with various physical and chemical stimulations and electrical phenomena of one kind or another. However, these are not the significant things about it. The significant fact with which we are dealing is the whole complex phenomenon in its entirety.

In the field of economics the situation becomes even more involved and complex because we are considering not the psychology of an individual but the behavior of groups of individuals with regard to other groups and are also concerned with their relationship to various materials and commodities. Yet there is no question but in this field there are laws which operate in spite of Federal farm board legislation

and the A. A. A. or any other governmental organization. It seems to me evident that much of the difficulty of the past years during the depression is due to the fact that many economists do not use the scientific approach to their problems. Although some of them use this approach there is such disagreement as to valid methods that great confusion has resulted. It is also entirely possible if not altogether probable that some of the so-called natural laws which have been thought to operate in the economic field are not valid. This does not mean, however, that such law is wanting and that it may not be discovered if studied in an effective manner.

In our personal relations with others natural law is operating, also. The so-called laws of friendship have a very real meaning. It must be perfectly obvious to all of you that certain reactions in other people will follow certain courses of action on your part. It is quite possible to make another angry or to arouse many other positive or negative reactions at will.

The field of ethics has to do with personal conduct as related to what is right. Here, conduct must be judged in the light of the society in which it occurs. A thing is good or bad, moral or immoral, only when related to some specific situation or environment. Still there is no chaos, though some would say that there was. I recall hearing a famous criminal lawyer discussing this matter before a gathering of college students at Wesleyan University, Connecticut. The whole effect of his talk was to leave the students with the idea that there was no basis for judging conduct as moral or immoral, good or bad, and the general concept was that society had no right or justification in punishing criminals for what they do because we had no valid standards of what is right or wrong. It would seem to me that this conception was contrary to fact at least insofar as holding that there was no way to determine what was right or wrong. In this day and age and in our society a person of good moral character is a perfectly definite sort of person. We know what to expect in the way of behavior from such an individual. Each one of us has friends about whom we would not believe a report of their having done an immoral or disgraceful act. On the other hand, we may also have acquaintances about which such reports would be accepted as the thing to be expected. A possible concept of ethics might be stated after this fashion — Behavior is right or ethical if it is in accordance with natural law operating in a constructive manner. This has to do only with human behavior as there is no ethics in the field of physics and chemistry.

In considering any behavior the level of the natural law that is operating must be considered. A thing may be right at one level and wrong at another. Certain behavior for example may be quite moral on the biological level with no immoral social implications whatever in a society like that of the early Polynesians, whereas the same course of action might be highly immoral in our own society judged on the basis of its biological, economic or social significance.

It is not my purpose to discuss ethics further than to point out the fact that natural law is operating in this field also. It is my firm belief that there is a fundamental and universal law governing human con-

duct under which human beings can achieve the best possible and most satisfying relationships. This has to do with many things that are known and recognized. The qualities of honesty, loyalty, truth, decency, kindness, unselfishness and the like are constructive in their effect upon individual and social life and in the long run will make for a better society than their destructive counterparts. It is obvious that if individuals and nations conducted themselves along these constructive lines the chaos which now confronts the civilized world would not exist. The point is emphasized here that any problem of ethics can be approached effectively by using essentially what we understand as the scientific method. It is granted without argument that our knowledge of natural law is incomplete, particularly at the economic, social, ethical and spiritual levels and that the technique of the chemistry laboratory cannot be carried over directly into the field of sociology and ethics. Not so long ago, however, chemical and physical laws were also unknown. Certainly no scientist can take the position that anything will be impossible in the future in the way of understanding and in controlling our universe. Further and more important, I would maintain that the scientific method is the most effective approach we have in dealing with our problems of whatever sort and can be taken as a working hypothesis upon which we can base our activities. At least, until we find a better one it will go far in giving meaning to our universe in fields where otherwise chaos and confusion seem to exist.

I hope that I am not being misunderstood. It is the farthest from my desire to advocate that the members of this society become less zealous in doing effective work in the science of horticultural research. Rather, it is to point out that we as scientists should realize more fully that in the scientific method we have an extraordinarily effective technique that can be brought to bear upon the problems outside the field of the physical and biological sciences. Further it is our opportunity and obligation to take some responsibility for the social and political order in which we work and which makes our work possible at all. With such a broad concept of responsibility the scientist would not abandon the scientific method when he closes the door of his laboratory each day, but would carry the same critical and dynamic approach with him wherever he goes.

In these troublous times when four-fifths of the nation paused to hear President Roosevelt's statement of the crisis with which we are confronted, we as scientists are in a favored position to be of outstanding service. We, more than any other group, have the approach that will be most effective in meeting the problems raised by events as they come provided, of course, that we realize at least some of the social implications of the scientific method.

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